Agricultural Policy Impact on the Stability of Farm Income and Water Use in the North-East of the Syrian Arab Republic

Final Report

By: Ahmad Sadiddin

Thesis Supervisor: Dr. Carlo Cafiero
Programme Coordinator: Prof. Antonio Cioffi

Research report submitted in partial fulfilment of the requirements of the doctorate degree in agricultural economics and policy under the doctorate programme of Improvement and Management of Agricultural Resources and Forests
Dipartimento di Economia e Politica Agraria
Università degli Studi di Napoli Federico II

Napoli, novembre, 2009

Acknowledgements

The accomplishment of this paper required a collection of massive data, both primary and secondary. For this, I would like to thank all people and institutions that provided me the necessary help and assistance during data collection stages, which are the National Agricultural Policy Center (NAPC) in Damascus, the Departments of Agriculture and Agrarian Reform in Al-Hassakeh, Deir-Ezzour and Al-Rakka, and the General Commission for Agricultural Scientific Research in Damascus.

In addition, I would like to express warm gratitude to **Mr. Atieh El Hindi**, the NAPC Director, for allowing me the access to NAPC library and database that were of great usefulness to the accomplishment of this thesis. Many thanks as well to **Mr. Haitham Al-Ashkar**, NAPC Deputy Director, for his support every time I visited NAPC for collecting information. Special thanks to **Ms. Ilaria Tedesco** for the time spent with me during the initial phrase of setting up the mathematical programming model used in the analysis when she was the junior consultant at the FAO Project GCP/SYR/006/ITA in Damascus. Many thanks too to **Dr. Massimo Gioia** for his assistance at the stage of setting up the analytical model. Many thanks as well to my colleagues **Basima Atiya** and **Mohammad Ali Mohammad** for their help and assistance in collecting field data and information.

My gratitude also to **Prof. De Stefano**, the President of the Centro di Portici, for his psychological support especially at the beginning of my stay in Naples. Special thanks as well to **Prof. Marenco** and **Dr. Luigi Cembalo** whose courses were of direct usefulness for my thesis. I will also express warm thanks to **Dr. Fabian Capitanio** for his constant availability to help me when he was my officemate and after. Many thanks also to all people that I met at the Department of Agricultural Economics and Policy (Naples) and to all the researchers of the Centro di Portici who all made the working environment friendly and productive.

Special thanks to **Prof. Cioffi,** the Coordinator of the Doctorate Programme for his great psychological support he provided me as a doctorate student as well as for his fruitful advice and valuable suggestions that guided me not only to accomplish this thesis, but also for the entire activities of the doctorate programme over the three years.

This work may not have been accomplished without the great and wonderful support that I received from **Dr. Carlo Cafiero** who was not only my advisor but was also a personal friend in all aspects. Working and studying under his supervision was not just useful at the professional level but was also a real pleasure. He made my stay in Italy easy and beautiful although I was away from Country and far from my family. Carlo's advice and assistance were not confined to the work on the thesis but were extended to all other aspects of my study in Portici for which he was available every time I asked him to provide me with help or advice. His work and research commitments have forced him to be physically away from the University for six months, but this did not constrain his duty as my tutor and his goodness as a friend. Carlo allowed me to stay at his house for free while he was away in California, offering me a free access to his great library and other resources that are available at his house. In the meantime, he exploited all opportunities and/or instruments to communicate with me using all modern communication technologies to make sure that I am on the right track in my studies. In brief, I will need a lot of time and pages to describe how Carlo has helped me and how. To him, I express my warmest gratitude and acknowledgement.

A final word is to thank my personal friends who embraced me as a family when I was away from my family not to the advice and suggestions of some of them at least regarding this dissertation. I namely mention: **Andrea Borlizzi**, **Alessandra Borrello**, **Luigi Castaldi, Francesca Colantuoni, Michele di Domenico, Davide Longhitano, Lucia Mancini, Danila Rolli Antonio Stasi, Michele Vollaro**, and all the other colleagues that I met at the Centro di Portici.

Dedication

For my wife:

Yara

and my daughters:

Laila & **Naia**

Table of contents

List of Figures

Abstract

This thesis aims at measuring the impact of agricultural policy on water use and farms' incomes in the northeast of the Syrian Arab Republic. The scope of the research is confined to the three governorates of Deir-Ezzour (DEG), Al-Rakka (RAK), and Al-Hassakeh (HAG). The choice of these governorates, that together form the Northeast of Syria, is due to their heavy reliance on policy regulated crops, which makes them relatively more sensitive to any policy reform. Moreover, the negative impact of the current policy on water balance is evident in the Northeast, especially in the area of Al-Khabour basin, located almost entirely in HAG.

In the thesis, irrigated agriculture of the Northeast of Syria has been modelled by a set of representative farms, using the General Algebraic Modelling System (GAMS). The representative farms' programming models are calibrated on data on observed cropping patterns and water use of 2005. Then, the policy reforms that have occurred after 2005 are considered in the models by changing the values of the relevant policy parameters and new baseline results obtained, inclusive of the most recent implemented reforms.

The comparison between the baseline results of 2005 and the post-reform baseline results show that the recent reform is expected to have a limited impact on water use and farm income. Predicted changes in water use are less than +5% on average, over the entire region, although they vary across the three governorates of the region, with negative change in Al-Hassakeh, and positive in Al-Rakka and Deir-Ezzour. On the other hand, changes in income levels and stability are more noticeable in the three governorates and are always positive. The changes in average income levels range from +15% in Deir-Ezzour to +3% in Al-Hassakeh. The impact on the stability of income is of the same magnitude in percent terms. It is of interest to note that the impact of the recent policy reforms, due to the stabilization of maize price, is greater on income stability than on average income levels in the three governorates.

The next analysis has involved simulation of alternative policy scenarios, including introduction of modern irrigation technology, reform in the farm credit system, and stabilization of alternative crops' prices. The simulations reveal interesting policy implications. They illustrate that adoption of modern irrigation techniques, even by all farms in the region, would not solve the water scarcity problem in Al-Khabour basin where there will still be a noticeable deficit. This is due to the still low efficiency of modern irrigation schemes in the current condition of the region, but also because our model predicts that water saved thanks to the adoption of modern irrigation schemes will allow expansion of irrigated land. In addition, the results show that decoupling access to official credit from strategic crops would have negligible effects on cropping patterns and, consequently, water use. Similar results come out if the subsidy currently linked to cotton irrigated from private wells would be decoupled. Of the various possible simulated policies, stabilizing cumin price would have the largest positive impact on water consumption, because of expanding cumin cultivation, which is a crop with irrigation requirements, at the expense of wheat and other winter crops.

The thesis adds to the evidence that price policy is potentially the instrument that affects farmers' decision the most. If effective in stabilizing price for water saving crops, this may be an important tool to combine farm welfare improvement with increased sustainability in water use.

Acronyms

ACB	Agricultural Cooperative Bank
AKB	Al-Khabour basin
CBS	Central Bureau of Statistics
CM	cubic meter
CMO	Cotton Marketing Organisation
DEG	Deir-Ezzour governorate
DERAHA	The region of Deir-Ezzoour, Al-Rakka, and Al-Hassakeh governorates
GCM	General Company for Mills
GECPT	General Establishment for Cereal Trade and Processing
GEF	General establishment for Feed
GESI	General Establishment for Sugar Industry
GESM	General establishment for Seed Multiplication
GOS	Government of Syria
HAG	Al-Hassakeh governorate
MAAR	Ministry of Agriculture and Agrarian Reform
MOI	Ministry of Irrigation
NAPC	National Agricultural Policy Center
NPCMI	National Project for Conversion to Modern Irrigation
RAG	Al-Rakka governorate

Introduction

By the year 2050, it is expected that the number of people to be fed will be increased by three additional billions, in addition to the already existing 6 billion people. Food production may need to increase by about 80% compared to the level of the year 2000. If no improvement will take place in the efficiency of water use, agricultural water consumption has to increase by the same percentage (De Fraiture *et al.* 2004).

Nowadays, irrigated agriculture provides some 40% of the world food production on only 17% of the total cultivated land. It is estimated that 60% of the extra food required to meet the increasing world demand must come from irrigated agriculture. Most of this increase must come from improvements in the existing irrigation systems as new sites for further development are scarce. About 75% of total irrigated land is located in developing countries where agriculture is dominated by smallholders, which means that significant improvements should be expected from a sector still dominated by small producers who may need help in order to adjust and adopt improvements in their farm practices (Hasnip *et al.* 1999).

In Syria, a developing Country whose economy is still dominated by the agricultural sector and is characterised by dry and semi-arid climate, irrigated agriculture is a vital component for its economic development. Irrigated cropping produces almost 100% of summer crop outputs and some 40-70% of the winter crops depending on rainfall availability that is characterised by considerable fluctuations from year to year. Consequently, the Government of Syria (GOS) puts in place many interventions to increase the irrigated agriculture area that indeed has increased steadily in Syria over the last decades, almost doubling since 1985. The rationale of expanding irrigation is that summer cropping is impossible without irrigation while the latter is necessary for winter cropping whether to reduce the effects of rainfall variability or/and to increase yields (NAPC 2005a).

Moreover, Syrian agriculture has been, for the last two decades, dominated by a few crops that are considered strategic from the viewpoint of the GOS. Cotton occupies about 20% of the irrigated area, while wheat (and barley to some extent) are cultivated in all parts of the Country, as a rainfed or irrigated crop depending on the rainfall and available irrigation water. The importance of these crops lies in the fact that wheat is thought to be the main source of food for the Syrian population and the GOS has always attempted to maintain a high level of self-sufficiency in this politically sensitive commodity. Cotton is the second main provider of foreign currency (after petroleum) necessary to finance imports and to improve the position of balance of payments, and when coupled with sugar beet and wheat they together form the main providers of raw materials for a bulk of the public sector industry (Westlake 2001).

That is why the GOS has always paid attention to these three crops, whether through favouring them by setting floor or fixed producer's prices that are usually set at a level higher than their counterparts prevailing in the world markets, or by favouring their production through the credit policy (refer to **section 2.2**). Consequently, Syria became a net-exported of wheat from early nineties. Cotton production has increases significantly so that Syria, in 2002, ranked the tenth in terms of total outputs and the fourth in terms of national yield at the world level. In addition, although the area cultivated under sugar beet does not exceed 3% of the total irrigated cropping area, it produces about one third of the Country demand for sugar processed in factories owned by the State.

However, since these crops require much irrigation water to yield acceptable levels of output in the context of the Syrian agro-ecological conditions, they have significantly contributed to the water scarcity problem, given the already limited water resources in Syria with respect to the Country's needs. Their negative effects on water is obviously observed in the north-east of the Country, especially in Al-Khabour basin (AKB), where cotton and wheat dominate the cropping patters. The problem of water scarcity is exacerbated given that Syrian water resources are quite limited as compared to the needs of the Country, in which recent estimates show that the overall water balance is negative with a deficit of more than three thousand million cubic meter (CM) per year. The AKB experiences the major part of the deficit where in 1999 its deficit exceeded the national one since some hydraulic basins demonstrated surpluses in that year (Varela-Ortega & Sagardoy 2001).

In addition, it is estimated that some 85-90% of the total use of the Country is consumed in agricultural production, where highly inefficient irrigation practices are predominant. Recent estimates record that about 85% of the irrigated land is still under flood traditional irrigation systems that cause enormous field water wastage. Furthermore, the record of water deviated to the irrigation of the strategic crops is estimated to be roughly of 7.5 billion CM, which is about 45% of the total water use of the Country and 55% of the agricultural use (Sadiddin 2009a).

In addition, several other factors are challenging the development of Syrian agricultural sector, including population growth and urbanisation, changing food habits, and most importantly the increased exposure to external factors resulting from the steadily increased integration of Syrian economy with the international markets. The latter will require the Syrian farmers to produce more in compliance of with the international standards. Doing so while coping with the shortage of water will require additional efforts, for which the agricultural support system will have to provide guidance and support (Lançon 2005).

Farmers' revenues are also at risk, due to the limited size of most farms and growing competition from imports. Moreover, farmers will be more exposed to risk as a consequence of the gradual withdrawal of the Government support that demonstrated its first strong sign by the recent dramatic increase of diesel price by about 235%, after a long period during which diesel was highly supported. Furthermore, this withdrawal may be very soon extended to the price support policy as this policy has caused drainage on public money, since the domestic prices of most strategic crops are set at a level higher than their international counterparts, causing a drainage on the public budget. In 2000, wheat, cotton and sugar beet caused a public loss of about SP 36 billion, a sum that formed 4.5% of the Syrian GDP then (Westlake 2001).

Given the above, the first objective of this research thesis is to assess the impact of the current policy on the agricultural use of water in the North-East of Syria, and to measure the impact of possible changes in the cropping patterns or/and the irrigation techniques adopted by the farmers as a result of foreseeable policy changes. In addition, one of the predictable side effects of any policy reform is the modification of the exposure to income and consumption risk of farmers and their families, leading to the other objective of the this thesis, which is to evaluate the potential additional risks to which farmers may be exposed as a result of the policy reforms. The scope of the research is confined to the three governorates of Deir-Ezzour (DEG), Al-Rakka (RAK), and Al-Hassakeh (HAG). The choice of these governorates that together form the northeast of Syria is caused by their heavy reliance on strategic crops that make them relatively more sensitive to any policy reforms. Moreover, the negative impact of the current policy on water consumption is evidently observed there especially in HAG where the AKB is located.

The analytical method used in the analysis is the representation of the irrigated farms of the region in question through a set of mathematical programming models coupled with farm representation techniques. This method allows deriving the supply functions of agricultural outputs and the demand functions for agricultural inputs (such as water and labour) of the representative farming systems, it also allows aggregating these the individual functions to the governorate level and to the level of total targeted region. These aggregate water demand and output supply functions are then used in assessing the incidence of possible alternative policies on water use and crops' production. In addition, by assuming that incomes of the farming households generated outside the agricultural sector hold unchanged, farms' gross margins and 'certainty equivalents' are used as an indicator of income level and stability respectively, by simulating the impact of some expected policy reforms on them.

The thesis is organised in five chapters. The first chapter is devoted to literature review and it is composed of five sections. The first section is a review of risk issues related to agricultural production. Definitions of risk and uncertainty as well as their sources and consequences are reviewed and discussed. Moreover, risk management institutions and mechanisms are reported and assessed. The second section is devoted instead to the importance of irrigation and water management for agricultural and rural development. In this context irrigation current and alternative policies and institutions related to irrigation water management are reviewed and assessed. The third section provides a discussion on alternative analytical methods, justifications to the choice of the adopted method are discussed through reviewing the strengths and weaknesses of most alternative approaches in light of the scope and the objectives of this thesis. The last two sections are then devoted to a critical review of the past research on water and risk issues in Syria to further justify the choice of the topic and the analytical method adopted through demonstrating the novelty of this thesis.

The second chapter is focused on describing the general farmers' environment within which the targeted farmers operate. It starts with a general description of the study area, followed by brief description of public policy and socio-economic factors surrounding farmers and affecting their behaviour. The third chapter presents in details the elements of the analytical model and describes the data used in the analysis. Setting up and solving the mathematical programming models are presented and the model validation is then described and discussed.

The fourth chapter is a presentation of the results of selected policy simulations. It is composed of two man sections. The first demonstrates the expected impact of the recent policy reforms that took place between 2005 (the reference year of the study) and 2009, while the second section illustrates the predicted effects of some other scenarios. The fifth and last chapter of the thesis presents a discussion of the results, their policy implications and their limitations. The chapter is ended with a number of suggestions for future research.

Chapter 1. Literature Review

This chapter is devoted to review the literature related to the topics of this thesis. It starts with a conceptual review of risk and uncertainty that covers their definitions, sources and consequences with special focus on agriculture. Risk management mechanisms and risk sharing institutions are then discussed with an emphasis on the potential role of public policy. Subsequently, a similar section is devoted to irrigation water use. The relevance of irrigation for agricultural risk mitigation is presented together with potential problems usually faced in managing water as a scarce resource and the role of public policy to deal with such problems.

The third section of the chapter reviews the literature of applied economics on decision making under uncertainty. The rationale behind the choice of the analytical method adopted in the study is presented through discussing alternative research methods in light of their strengths and weaknesses and in light of the objective of the thesis. The chapter ends with a critical review of past studies on water use and risk in the Syrian agriculture highlighting their strengths and weaknesses for the sake of demonstrating the novelty of the thesis topic and analytical method.

1.1. Risk related issues in agriculture

1.1.1. Risk and uncertainty: definition, sources and consequences

Agriculture has been often considered in economic textbooks to be a case of economic activity burdened by risk. Many risk management tools such as forward contracts and futures markets have their origin in agriculture. In addition, many support programmes are warranted as safety net for agricultural producers against risk. While there is nowadays a general consensus on the economic definitions of risk and uncertainty, it is maybe useful to illustrate the way different authors and researchers have approached this matter (Coble & Barnett 2008).

In some economic literature, risk and uncertainty are not strictly interchangeable. In this regard, risk has a rather precise meaning distinct from the subjective sense of uncertainty. Therefore, risk is confined to conditions where probabilities can be attached to the occurrence of a specific event influencing the outcome of the decision making process. Uncertainty, on the other hand, refers to situations where it is impossible to attach probabilities to the occurrence of events (Ellis 1993).

However, research of risk analysis has not been recently based on this distinction between risk and uncertainty. This is because what is relevant in most decision making is not a superhuman knowledge concerning the likelihoods of uncertain events, but it is the relevant decision maker's personal degree of belief about the occurrence of events. In this context, *risk* still refers to probabilities, but now they are subjective probabilities attached by the decision makers' beliefs. Of course, the analysis of risk does not require only probabilities, but it is important also the way they enter economic decision. Thus, *risk* is used to describe the entire mechanism by which decision making is done with respect to uncertain events. Uncertainty, in contrast, has nothing to do with probabilities or their nonexistence, but it is just a descriptive sense to character the economic environment confronting agricultural activities (Ellis 1993).

Hardaker *et al.* (2004) define *uncertainty* as an imperfect knowledge while they define *risk* as uncertain outcomes, particularly exposure to unfavourable consequences. With the same line of concepts, Robison & Barry (1987) define risky events to be those events whose outcomes are not known with certainty, but they go on to state that uncertain events are only important when they alter a decision maker's material or/and social well-being. Newbery & Stiglitz (1981) argue that farmers are concerned with income variability and how it affects consumption rather than variable factors such as price or yield. They also argue that price variability itself is not the appropriate metric to judge risk. They also discuss the distinction between risk and uncertainty, but take a subjective probability approach as suggested by Savage (1954) to indicate that the distinction is largely irrelevant. However, Newbery and Stiglitz (1981) do make a strong assertion that it is relevant to distinguish between systematic and non-systematic risk, so that systematic risk follows a predictable pattern with known relationships where non-systematic variability arises from shocks and other variability in markets supply or demand due to unforeseeable forces that come to bear on market prices.

Some authors define *risk* as the *uncertainty* that matters, and may involve the probability of losing money, causing harm to human health, repercussions that may affect important resources such as irrigation water and credit, and other types of events that affect a person's welfare. So uncertainty, which is a situation in which a person does not know for sure what will happen, is necessary for risk to occur, but uncertainty need not lead to a risky situation (Harwood *et al.* 1999). Alternatively, Chavas (2004) defines risk as representing any condition where some events are not known with certainty.

We can infer from the above review that there is no clear consensus on the distinction between risk and uncertainty. One can, however, notice two schools of thought, one arguing that risk and uncertainty are not equivalent and that the distinction between the two is the ability to make a probability assessment, while the second deals with both of them as synonyms. However, an important aspect of the debate about the distinction between risk and uncertainty is about the existence and interpretation of probability. Although this discussion is intuitive on the theoretical basis, but has not led to much empirical analysis and thus we do not draw any sharp distinction between risk and uncertainty and uses the terms interchangeably in this thesis.

Sources of risk and uncertainty in agriculture are defined and explained in many economic textbooks and other sources. Ellis (1993) classifies these sources under four main categories: natural hazard, market fluctuations, social uncertainty and state actions and wars. Adverse climate and other natural hazard phenomena (such as pests and diseases) may affect the outcome of planting decisions at any stage from cultivation until harvest. In addition, sale prices of outputs are unknown at the time decisions are made due to the long lag that separates production decisions from output sale. Note also that the capacity to control pests and diseases may depend on the ability to purchase relevant inputs.

In addition, Both Huirne *et al.* (2000) and Hardaker *et al.* (2004) distinguish two major types of risk in agriculture. First, *Business risk* includes production, market, institutional and personal risks. Production risk is caused by unpredictable weather and biological performance. Market risk is caused by fluctuating prices of outputs and, sometimes of inputs. Institutional risk is due to unpredicted government actions and policies, for instance, laws constraining the use of pesticides for environmental concerns. Personal risks are due to uncertain life events such as death, divorce, or illness. Second, *financial risks* result from different means of financing the farm activities. Relying on borrowed funds involves that interest charges are met before equity is rewarded which may create risk due to leverage. Additionally financial risk is exacerbated when loans are unavailable due to a rationing policy, which is common in developing countries due to the scarcity of credit resources, this may cause the interest rates of alternative sources to rise significantly further worsening the already existing financial risk.

Baquet *et al.* (1997) define five major sources of risk that are almost identical to those defined above although they are classified differently using sometimes other names for the same concepts as: production risk, marketing risk, financial risk, legal risk, and human resources risk. Alternatively, Moschini & Henessy (2001) prefer to talk about sources of uncertainty in agriculture, singling out production uncertainty, price uncertainty, technological uncertainty, and policy uncertainty.

The World Bank (2000) and Holzmann & Jorgensen (2001) classify risks in six different types: natural, health, social, economic, political and environmental. They also cross this typology with an additional dimension of systemic characteristics of different risks: micro or idiosyncratic risk that affects the individual, Meso-risk affecting a whole community, and Macro or systemic risk affecting a whole region or Country. All the risks they mention affect farmers in some way, particularly natural (rainfall, landslides, floods, droughts, etc), health (animal and plant) and environmental risks. Furthermore, most of these risks eventually take the form of economic risk that affects the stream of income, consumption and wealth.

Any classification of risk sources underlines the fact that an individual farmer may be facing very different risks at the same time. In these conditions, the optimal choice of a strategy to deal with them requires that correlations among risks be accounted for. A deep review of the literature on the sources of risk in agriculture, correlations among them and their relative importance is also presented in Coble & Barnett (2008). Moreover, all classifications of risk sources discussed above consider several sources of risk and uncertainty that are not intrinsic for agriculture and they are embedded in all economic activities such as those classified under personal, health, institutional, and social sources of risk.

This means that the only sources of risk that are inherent in agriculture are those that can be classified under natural hazard risks and market risks. The first is due to the high reliance of agricultural production on natural resources and phenomena, but also due to its high exposure to unfavourable weather conditions. The second is mainly caused by high fluctuations in prices of primary agricultural products due to relatively inelastic demand for and supply of these products. Aspects of financial risks such as access to credit fall under market risks since poor access to credit is caused by failure of credit market. Consequently, we care in this paper about these two classes of risk that make agriculture an economic activity in which risk and uncertainty form a major characteristic.

Having defined risk and uncertainty and their various sources, one may ask: “does risk matter?” A simple direct answer will be ‘yes’ if they alter the well-being if the decision maker in question. Hardaker *et al.* (2004) argue that people are usually risk averse, implying that although they do take risks, the certainty equivalent they assign to any risky prospect is less than the expected money value of that prospect. So people do take risks provided there is an incentive to do so; however, their degree of risk aversion may differ. This implies the existence of a utility function of income that is of a positive but decreasing slope. In addition, Hardaker *et al.* (2004) state another reason why risk must matter in agriculture, and they call it *downside risk*, which is taken to mean that the payoff from a risky prospect will be reduced if conditions are not as assumed. This type of risk, they argue, can arise from two different causes. First, it can occur when decisions are made under assumed certainty based on ‘best estimate’ of the consequences. Second, it may arise when a risky outcome depends on a non-linear interaction between a number of uncertain quantities.

Furthermore, Ellis (1993) states some common consequences of risk and risk aversion. He argues that risk aversion results in sub-optimal decisions at the microeconomic level. It has been observed that poor farmers apply sub-optimal quantities of inputs (e.g. fertilisers) to guarantee a minimum level of output if unfavourable weather conditions take place. In addition, risk results usually in slowness in the adoption of innovations such as high yielding varieties and may cause poor farmers to continue growing subsistence crops even when food may be purchased more cheaply, an observation also made by Upton (2004). Risk has also a greater impact on poor people, thus reinforcing social differentiations.

Roberts *et al.* (2004) argue that risk often influences farmers’ production incentives even when costs of risk-coping are small, when the latter are large, risk affects production incentives in entirely different ways, and it may even influence the structure and organisation of the agricultural sector. In other words, risk matters even when all markets are functioning perfectly. However, if this were the case, people could manage risk using risk-sharing mechanisms. However, when markets are far from perfect as usually the case, adverse selection and moral hazard that are associated with asymmetric information cause the risk-sharing mechanisms to fail.

Roberts *et al.* (2004) also criticise the emphasises in economic literature on the importance of farmers’ attitudes towards risk, while risk can affect farmers decision through different channels. For example, greater uncertainty about rainfall may alter a farmer’s fertiliser applications regardless of her attitude toward risk. In other cases, risk consequences are similar regardless of its source; however, policy implications may be different according to the channel through which risk affects farmers’ decision. Therefore, it is important to evaluate the relative importance of different risk channels. The idea is that risk is difficult to measure and its effects can be easily confused with effects of other factors such as location, climate and soil quality.

1.1.2. Risk management: mechanisms and institutions

If risk matters for whatever economic activity, risk management becomes a very relevant issue for any decision to result in acceptable outcomes. Risk management is a systematic application of management policies, procedures and practices for the sake of identifying, analysing, assessing, treating and monitoring risk, with the objective of avoiding, mitigating, or coping with it. It should be an integral part of any 'good' management since it is a way of organisation to avoid losses and maximise opportunities. It is not a set of principles to follow or a group of practices to pursue, once and ever. This is impossible in a changing world where the nature and the consequences of risk are changing too. It is rather an ongoing adaptation process that must be incorporated into all aspects of farm management (Hardaker *et al.* 2004).

Hardaker *et al.* (2004) distinguish two types of risk management strategies: on-farm strategies and risk-sharing strategies. The former can be classified under the following five headings: avoiding or reducing exposure to risk, collecting information, selecting less risky technologies, on-farm and off-farm diversification, and flexibility. They define the strategy of avoiding or reducing the exposure to risk to be all preventive measures that reduce or eliminate the possible occurrence of unfavourable events such as accidents, fire, the spread of disease, etc. But it also includes actions and measures that abate the negative consequences when an unfavourable event occurs.

While the benefit of more and better information is obvious regardless of the decision maker's attitude towards risk, they also argue that risk also can be sometimes managed and mitigated by selecting appropriate technologies that give higher and more stable returns. Diversification of on-farm activities and off-farm income sources is also regarded always as a good strategy to smooth income, which helps smooth consumption. Flexibility of farm structure might help mitigating risk in a fast changing world. Asset flexibility is an example that implies investing in assets that have more than one use or/and can be with slight adjustments adapted to other uses. The same idea may apply to product flexibility, so that the focus is on producing products that have several uses and maybe several markets. Keeping fixed costs as low as possible while relying more on variable costs might be a good strategy to manage risk, e.g. it may be better to lease machinery rather than purchase it. Another aspect of flexibility is related to time that entails the speed in which necessary adjustments are made (Hardaker *et al.* 2004).

Concerning the risk-sharing strategies, they define five mechanisms that farmers can use to manage risk. First, external credit can be used to finance farm business. However, an increase in financial leverage may magnify the impact of farm returns, and therefore, this raises the question of optimal financial structure for the farm, whose determination depends on risk preferences that are usually affected by the information available to the farmer on future income levels. Second, insurance can also play a role in farm risk management in form of contracts against fire, theft, death, workers' injury, etc. However, most insurance programmes are provided under subsidised government schemes due to market failures that characterise insurance markets. Third, share contracts (e.g. sharecropping arrangements) are also a mechanism that helps farmers sharing risk with others, these are very much common in developing countries although still practiced in some developed countries such as the USA.

However, Upton (2004) considers share contracts to be a risk-spreading mechanism rather than a risk-sharing. He confines risk sharing to the mechanisms when various individuals earning from different sources of income agree to pool at least part of their incomes and share the associated risks, which is a strategy that works out only when income sources are not positively correlated. Risk-spreading, on the other hand, occurs when a single risky project is shared by more than one individual as the case of sharecropping.

Forth, contract marketing whether through price pooling or through forward contracts, are widely used in developed countries to manage price risk, and they are used to some extent in developing countries. Price pooling is operated by a group of farmers collectively buying their inputs or/and selling their outputs through a cooperative or a marketing board. It help farmers in two different ways: protecting individual farmers from short-term fluctuations of prices through some kind of averaging, and obtaining lower input prices and higher output prices through gaining some market power. However, forward contracts are viewed by Hardaker *et al.* (2004) a better strategy as long as risk management is concerned, since farmers under such arrangements receive guaranteed prices for their outputs regardless of the market conditions. Fifth, derivatives trading can be used as well to reduce price risk through hedging on commodities futures market and options trading.

Other economists have viewed and classified strategies and mechanisms available to farmers to deal with risk in different ways, each may have different policy implication. Dercon (2002), focusing on conditions of developing countries, distinguishes risk-management tools from risk-coping strategies. Farmers use the former in an attempt to reduce risk ex-ante, so they are income-smoothing strategies. Examples are diversification of farm activities and income sources achieved by combining activities with low positive correlations, and income skewing achieved by carrying out only low-risk activities even at the cost of lower returns. Risk-coping strategies includes self-insurance through precautionary savings and informal group-based-risk-sharing to deal with outcomes of income risk in order to smooth consumption. Farmers can insure themselves by building assets in good years to deplete them in bad years, while group-based-risk-sharing can be made among members of formal or informal groups to support each other in case of hardships.

World Bank (2005) classifies risk management mechanisms and strategies under two main groups: formal and informal, each in turn includes ex-ante and ex-post strategies. Informal ex-ante strategies are characterised by diversification of income sources and choice of production technology. One strategy producers can employ is to avoid risk. People caught in the so-called 'poverty trap' may be very risk-averse and they often avoid activities that involve risk but could carry larger gains. However, once people have decided to engage in farming activities, the production strategy is of essential role in reducing negative risk effects. Crop diversification and intercropping systems are in many places means to mitigate risk. Households also seek to smooth income by diversifying its sources. Buffer stock accumulation of crops and liquid and the use of credit undoubtedly provide tools to smooth consumption. The adoption of advanced technologies such as irrigation, fertilisation and resistant varieties can also be useful. Sharecropping arrangements in land renting and labour hiring can also provide an effective way of risk management through sharing risk between individuals, thus reducing producer's exposure to risk.

Informal ex-post strategies are typically the sale of assets (land and livestock e.g.) or the reallocation of family labour resources. Gadgil *et al.* (2002) argue that farmers in the south of India can switch quickly from 100 percent on-farm labour activities to largely off-farm activities if the monsoon rains are expected to be poor.

Formal risk management mechanisms are in turn classified as publicly provided or market-based. Government policy can play a major role in agricultural risk management both ex-ante and ex-post. Education and services provided by the agricultural extension help familiarise producers with the consequences of risk and help them adopt strategies to deal them. Government can also reduce risk effects by developing infrastructure and adopting social schemes and cash transfers for reliefs after shocks have occurred. Market-based strategies proposed by World Bank (2005) are forward contracts that allow producers to lock into a certain price. In specific markets and for certain products, forward contracts have evolved into futures contracts, traded on regulated exchanges on the basis of specific trading rules and for specific standardised products. This reduces some risks associated with forward contracts such as default. The development of price options represent a further evolution in hedging opportunities for farmers, which allows farmers to benefit from a floor price but also from the possibility of taking advantage of positive price changes. A detailed description of these market derivatives is available and their usefulness for managing risk associated with market fluctuations is described in Hull (1996).

While futures and options are appropriate instruments to deal with spatially correlated risks, World Bank (2005) argues that crop insurance is appropriate for independent risks such as risks related to agricultural production. However, these risks as they lack spatial correlation, they also lack high degree of spatial independent and therefore, crop insurance markets do not work at their best.

Coble (2009) argues that more concrete risk management strategies can be grouped into three categories according to the objectives they are supposed to achieve which are: risk prevention, risk mitigation and risk coping. The first includes measures that help reduce the probability of an adverse event occurring, the second includes practices and measures that help reduce the potential impact of an adverse event, while the third includes measures that assist in relieving the impact of a risky event once it has occurred. So this classification of risk management strategies go in line with that pursued by Dercon (2002) even though the latter uses somehow different terminology, since prevention and mitigation strategies aim at income smoothing while coping strategies aim at consumption smoothing. Coble (2009) also bases the possible strategies on arrangements made at different institutional levels: farm household or community level, market-based mechanisms and public policy exactly as in World Bank (2005) and therefore no need to repeat which measures fall in which group.

Fafchamps (2003), on the other hand, argues that the distinction between ex-ante and ex-post strategies, although useful, can be misleading since many ex-post mechanisms require ex-ante planning if they are to be effective. Using savings to cope with potential hardships is effective only if savings are available when they are needed. He proposes that a more useful distinction is between strategies that seek to reduce risk itself and those that insulate welfare from risk, which can be called preventive and curative measures respectively. Fafchamps (2003) also argues that care should be taken with using the term 'risk management' when referring to the poor since much risk is unmanageable by the poor, and so the term belittles their experience. Therefore, risk-coping is a preferable term that encompasses all possible strategies by which individuals to reduce the negative effects that risk has on their well-being, whether they are ex-ante or ex-post strategies.

Ellis (1992: 1993) and Upton (2004) emphasise the role of public policy in helping farmers to deal with risk and reduce its negative impacts on their welfare. They classify proper policy instruments according to different sources of risk, assuming that the most relevant ones are risk associated with natural hazard and market risks. For the former, Ellis (1993) defines three possible measures government can promote. Promoting irrigation is the most obvious policy in response to natural uncertainty when it is expressed in rainfall variability. Crop insurance may be a solution in face of potential disasters, but it faces almost insuperable practical problems since average risk aversion needs to be demonstrably high for the benefit of a crop insurance to outweigh the formidable administrative costs. And so he argues that the development of resistant varieties may be a much better option due to its lower cost relative to its potential benefits.

For risks associated with the functioning of markets, price stabilisation is clearly the main economic argument against price risk. This in turn can take many forms, ranging from minimum floor prices to fixed producers prices. The pricing policy of the strategic crops in Syria is an example of this. However, price stabilisation policy may exacerbate income variance if yields remain highly variant when there is in place a ceiling price or fixed price. This is because under market conditions, prices rise in low yield years and fall in high yield years resulting in some smoothing out of annual incomes as stated by Ellis (1993). However, this is only true when markets are not largely integrated, when they are, price fluctuations are resulting from the interaction of supply and demand in national and international markets (Upton 2004).

Ellis (1993) and Upton (2004) recognise also the role that government can play in reducing farmers' exposure to risk through information diffusion since some risk aversion is partially attributed to inadequate information. They also regard credit provision as an effective tool to reduce risk aversion. This is because, as Eswaran & Kotwal (1989; 1990) argue, differences in risk behaviour do not necessarily result from differences in subjective risk preferences, but they may result from differences in the ability to manage fluctuations in income across time in order to ensure continuity of consumption. Ellis (1993) also argues that credit is useful for overcoming resistance to the adoption of new technologies. However, participatory forms of rural credit instead of agricultural development banks may be favourable since the latter with their subsidised credit to farmers have been rife with difficulties. Jaffer (1999) demonstrate how solidarity microfinance can play a major role in overcoming the problem of asymmetric information that cause conventional lending to fail. He shows how solidarity lending, instead, can reduce information costs especially when the institutional setting is weak and borrowers' projects are small, and thus he argues that it might be an alternative to the conventional lending to target the rural poor.

Having reviewed most individual and collective strategies that farmers can use to cope with risk and public policies that help farmers deal with risky events, it is interesting now to discuss their limitations since they do not always work, each one for specific reasons. Self- protection strategies pursued at the farm level face several technological and environmental constraints. Income diversification may be impractical if returns to alternative activities are too low to warrant investments in them or if increased returns require specialisation (Fafchamps 2003). In addition, many farms are already diversified regardless of risk aversion, since mixtures of activities make best use of available resources allowing more productive and sustainable crop rotations. Furthermore, the fact that returns from many different activities are positively correlated limits potential gains from crop diversification. Spatial diversification may solve the last problem by reducing positive correlations due to weather; however, this is only available to large business (Hardaker *et al.* 2004).

Diversifying income sources through engagement in off-farm income generating activities may also be regarded as an effective tool for reducing the effects of positive correlation between farming activities, but their availability depends on the functioning of labour markets and the availability of jobs opportunities outside the agricultural sector, which is largely determined by the overall performance of the economy and its development level. However, investment in education may be a best strategy to help find employment outside the agricultural sector. A case study in Syria demonstrate that the education is the most correlated factor with the economic well-being (UNDP 2005).

Flexibility is another risk reducing strategy that is constrained by technological and environmental conditions. The extent to which valuable resources must be sunk before income can be created limits farmers' willingness to risk such resources. That is maybe why flexibility is low in dry areas as short rainy seasons preclude crop diversification and the scope of crop intensification. This also is why farmers in such areas are reluctant to adopt new technologies and invest in high generating crops (tree crops e.g.), which lock them to the cultivation of very few products and causing them to lose profitable opportunities and limiting their capacity to adjust to shocks (Fafchamps 2003).

Hardaker *et al.* (2004) show that reducing exposure to risk from one side may increase it from another. Cost flexibility may require leasing machinery rather than purchasing them, labour may be hired on a casual basis rather than in form of permanent workers in order to keep fixed costs as low as possible. However, this may increase the risk since machinery provision market may fail due to the seasonality of agricultural operations, as demand for rental machinery is very high when it is needed. The same applies to labour especially in the peak harvesting seasons.

Some financial and institutional constraints limit also the benefit from pursuing less risky technologies. Irrigation is often regarded as a more reliable technology in areas characterised by high variability of rainfalls. However, access to irrigation may be costly and farmers may not afford to access it without substantial public support. Moreover, irrigation may be strictly regulated by public authorities that aim to protect water resources in areas where they are scarce. In Syria, e.g., there have been recently strict regulations for the issuing of wells digging licenses due to recent common fears that water underground resources are being depleted (Sadiddin 2009).

Farm households' efforts to accumulate assets and savings they can use to insulate themselves against risk are also constrained by the paucity of savings instruments available to them. However, many poor farmers save even if the return to liquid assets is negative. This is because they do not save to exploit financial opportunities but rather to accumulate a buffer stock to deal with emergencies even if the asset has a negative return due, for example, to high inflation rate. Furthermore, the ability to liquidate assets in order to deal with shocks is constrained by the property rights system. For this approach to be feasible, individuals must have well defined property rights on these assets (Fafchamps 2003). In Syria e.g., farmers who benefited from land reform, although have always had secure usufruct rights over land, were not permitted to sell it legally until recently (Wattenbach 2006).

Sharecropping is the informal mechanism that is most recognised as a risk-sharing mechanism or a risk-spreading strategy. However, its usefulness as an effective risk management tool is doubted since its practice is motivated by other factors beyond managing risk. Sharecropping, the way it is practiced in most of the world, is obviously a response to failure of factor markets, as two parties enter into a contract according to which one provides land and credit (the landowner) and the other provides labour (the tenant), so it is an effective mechanism for the tenant to access land and capital while it is an effective strategy for the landowner to avoid the ill-functioning of labour market. The fact also that output is shared according to pre-agreed proportions means that it aims to motivate the tenant for hardworking and reduce the supervision costs of labour consequently which may be considerable in larger farms. A case study in Syria (Sadiddin 2004) shows that larger farms are more likely to engage in sharecropping activities than smaller ones.

The implication of this argument is that if labour market functioning improves or if the landowner adopts a highly mechanised technology, sharecropping may become much less practiced. Sadiddin (2004) also shows that sharecropping is mostly practiced for less risky crops such as irrigated wheat and cotton that have minimum guaranteed prices by the government and enjoy relatively stable yields due to the availability of irrigation, a finding that supports the limited usefulness of sharecropping as a risk-sharing tool.

Risk-sharing mechanisms that rely on pooling risks through sharing incomes of different individuals of a single household or of a group of households of a community can also be effective only if the pooled incomes are not positively correlated, which is not the case in many rural areas where most people rely on a limited number of activities.

Market-based mechanisms are not without their limitations too. Concerning the use of forward contracts, futures market and options trading, although they may prove effective for the sake of risk management and smoothing income are still narrowly practiced even in developed countries, while they are still absent in developing countries. This is probably because using them effectively requires well-established financial markets that are, if they exist, far from being perfect in developing countries. In addition, using them effectively requires specific knowledge and skills that are not in the hands of farmers even in developed countries where farmers are still not motivated to acquire these skills due to the presence of many price stabilisation policies and subsidised insurance programmes.

Insurance as a mechanism of risk sharing has been largely criticised in economic literature for a number of reasons. As it is an appropriate risk management solution only for independent risky events, insurance markets do not work at their best since agricultural production risks are generally not spatially independent. Positive spatial correlation in losses limits the risk reduction that can be gained by pooling risks from different geographical areas. The lack of statistical independence is not the only problem with insurance in agriculture. Asymmetric information causes two other problems: adverse selection and moral hazard (Hardaker *et al.* 2004).

In the case of adverse selection, farmers have better knowledge than the insurer about the probability distribution of losses. Thus, the farmers have the privileged situation of being able to discern whether or not the insurance premium accurately reflects the risk they face. Consequently, only farmers that bear greater risks will purchase the insurance, generating an imbalance between indemnities paid and premiums collected. Moral hazard is another problem that lies within the incentive structure of the relationship between the insurer and the insured. After entering the contract, the farmer's incentives to take proper care of the crop diminish, while the insurer has limited effective means to monitor the eventual hazardous behaviour of the farmer, resulting in greater losses for the insurer (Coble 2009).

Furthermore, agricultural insurance is often characterized by high administrative costs. These costs are high, in part, due to the risk classification and monitoring systems that must be put in place to address asymmetric information problems. Other costs are associated with acquiring the data needed to establish accurate premium rates and conducting claims adjustment. Consequently, spatially correlated risk, moral hazard, adverse selection, and high administrative costs are all important reasons why agricultural insurance markets fail if they are not heavily supported by public policy (World Bank 2005).

Cafiero *et al.* (2006), in their review of the existing and alternative emergency measures in the various member states of the European Union (EU), conclude that the establishment of a common programme of insurance premiums' subsidies is highly unlikely due to the existing constraints on devoting more finance to agriculture in Europe. They instead propose an intervention based on supporting farmers' mutual funds and promoting access to credit, insurance and financial markets to make them easily accessible by farmers, a conclusion already reached by Cafiero (2005).

Wright (2004) brings the criticism against crop insurance further, stating that many countries are still investing in crop insurance at increasing rate, when such investments could have gone to fund research since there is huge evidence that agricultural research has been the driving force of agricultural development, while no respectful evaluation shows that revenue insurance has ever sustained a positive rate of return. Wright (2004) believes that the problem of crop insurance exceeds moral hazard and adverse selection. He shows how early literature on crop insurance mis-specified what farmers really seek to maximise by neglecting the role of diversification of income sources and that of consumption smoothing activities. Modern improvements, in turn, neglect the role of credit and savings that makes risk premium associated with normal changes in income negligible, and even less than the administrative costs of an insurance programme, explaining the reluctance of farmers to pay for unsubsidised conventional insurance programmes.

With the deepening of the financial and insurance markets in the 1990s, the idea of weather index products, which was first published in the middle of last century, got renewed attention in economics research as an attempt to overcome the problem of asymmetric information that characterises insurance markets. The idea is that these index products are calculated from observations of rainfall or/and temperature that are beyond the control of both parties. If the index falls below a pre-agreed threshold value, indemnities are paid by the insurance agency. These index products are also cost efficient and easy to administer since they are easy to measure at low cost and easy to calculate the probability that indemnities are due, making them superior to traditional insurance programmes (Hardaker *et al.* 2004).

In this respect, Cafiero and Cioffi (2004) believe that any future reform of the Common Agricultural Policy of the EU must consider further reliance on credit and finance to help farmers manage risk and stabilise their incomes. They recommend that a major role that governments can play in this respect is to provide information on weather, area, yields, prices and other useful indexes on which weather index contracts can be written and enforced, since the calculation of weather index requires quite large amount of data. This, of course, limits their use especially in developing countries where if such data are available, their reliability is probably flawed.

In conclusion, there are always some conditional factors that have to be present for many risk management mechanisms and strategies to be helpful, and public policy should be informed according to the specific conditions within which the targeted farmers operate. In order to be successful, public policy should depart from already existing mechanisms pursued by farmers. This is important to avoid that policy measures may replace farmers' own strategies and make them 'policy-dependent' exposing them to greater risk if policy proves to be unsustainable and need to be reformed. For example, policies that maintain macroeconomic stability would allow self-insurance mechanisms to work better through, e.g., reducing asset market risks. Another example would be policies that promote the integration of agricultural asset markets with wider economy since this prevents much of the covariance between asset prices and incomes.

In addition, where the farming sector still dominates the economy as the case in many developing countries, the development of other economic sectors is a crucial element of any risk management policy, since it is the most effective course to provide farmers and rural households with more attractive and diversified sources of income that are not highly correlated. Furthermore, there is still a pressing need for large public involvement in biotechnological development if poor farmers are to benefit from agricultural innovations. More attention also must be made on investments in public goods that reduce risks such as irrigation drainage systems and development of high yielding and resistant varieties.

Rao (2009) argues that public expenditure and policy actions in favour of agricultural research and development, improved water availability and control, integrated systems for training and extension services, access to rural credit, and the provision of market and physical infrastructure, played a historic role in getting agriculture moving ahead in countries as disparate as the United States and India, while they came to be emaciated in the very countries that had remained largely untouched by the "Green Revolution" of the previous quarter century. Therefore, there may be a need to find alternative policies and approaches to the currently prevailing ones, which may require reversing some of them back to old-fashioned land reforms, mobilization of surplus labour and collective action for infrastructure building, cooperatives for credit and input supply, and bringing the main role of the state back to be again responsible of regulating markets, organising research and extension as public goods, providing irrigation and infrastructure, and coordinating actions that will be needed to adapt to climate change, all vital areas where market failures strongly justify public intervention especially in developing countries.

Whether the role of the state can be still reversed to its "old fashion" remains an open question whose answer is more political than economic and anyhow it is beyond the objective of this review.

1.2. Water use issues in agriculture

The essence of water for socio-economic sustainable development is widely recognised. As population increases, development calls for increased allocations of water for various uses, intensifying the pressure on the limited water resources. The scarcity of water is maybe defined as the point at which the aggregate impact of all users impinges the supply or the quality of water to the extent that demands cannot be successfully satisfied. Water scarcity may include severe environmental deterioration such as river desiccation or pollution, declining underground water levels coupled usually with increased salinity, and increasing conflicts in water allocation where usually some people win at the expense of others.

In most countries, especially the developing ones, agriculture uses the bulk of water resources. Historically, large-scale water projects have played a fundamental role in poverty reduction through providing food security, protection from flooding and drought and expanded employment. Irrigated agriculture has been, in many cases, the driving vehicle of development supporting economic growth in the rural sector.

Globally, irrigated agriculture produces about 40% of food and agricultural commodities from only 20% of the agricultural land, implying a higher reliance of food security on irrigation (Lipton *et al.* 2003).

1.2.1. Irrigation and development: rationales and limitations

Irrigation can be broadly defined as the supplementation of precipitation by storage and/or transportation of water (Upton 2004), more precisely it is the process of supplying water as a variable input into crop production to even out the supply of water over time. Therefore, irrigated agriculture can be defined as agriculture where the water provision is augmented by the use of water command technology including the drainage of dispose of excess water (Hasnip *et al.* 1999).

Irrigation increases agricultural productivity and human carrying capacities per unit of land and raises farm output growth due to a number of reasons. First, irrigation reduces risk aversion due to adverse impact of rainfall variability on yields, which increases incentives to use inputs at optimal levels. Irrigation raises also crop yields directly by mitigating the incidence of water stress in plants caused by uneven water supply, and indirectly by the increasing the productivity of other variable inputs such as fertilisers (Ellis 1992).

Irrigation also permits the introduction of high yielding varieties and the intensification of agricultural production as it allows increasing the number of crops that can be grown sequentially in a certain land plot. It obviously allows uncultivated land, and sometimes uncultivable, to be brought to cultivation if the main constraint was water scarcity, and it allows the extension of cropping season. Irrigation also helps reduce year-to-year fluctuations in yields (Upton 2004).

Data analysis from Asia demonstrates that yields of most crops increased by 100-400% due to irrigation, which contributed to a reduction in food prices that has had a positive impact on real incomes of urban and rural poor. Therefore, irrigation brings about a more stable flow of income due to increased intensity of cultivation, improved yields, and new cropping mixes that result in higher values. This may cause an appreciation of land prices, which may be in favour of poor farmers when they are also landowners. It can also offer evenly spread employment and improved wage rates, which may improve security, reduce out-migration, contribute to the creation of new social networks, and enhance urban-rural contact (Hasnip *et al.* 1999).

Lipton *et al.* (2003) examines various impacts that irrigation may have on rural development and poverty reduction. He claims the presence of direct effects through outputs, employment and food prices. Irrigation boosts farm output and raises, therefore, farm incomes as long as increases in outputs outweigh potential reduction in prices. Irrigation also generates employment in rural areas via two major mechanisms. First, irrigation projects require labour for building and maintaining canals, wells and pumps, which may generate employment opportunities for rural poor with excess labour. Second, increased farm output would stimulate demand for farm labour. Thus rural poverty may be reduced. In some cases, effects might be extended to reduce migration to urban centres relieving the downward pressure on urban wages and upward pressure on housing and other urban infrastructure thus contributing to urban poverty alleviation.

Lipton *et al.* (2003) argues that the increased farm output may result in lowering prices of staples, especially in imperfectly open economies. Thus net purchasers of food will gain. Waged agricultural labourers will benefit from lower prices in addition to their benefit from increased employment. However, poor farmers outside the irrigation projects are usually harmed by reduced prices if they are net purchasers of food. But in total, irrigation is likely to contribute to rural development and poverty reduction through higher farm output, more employment opportunities and lower food prices.

But irrigation may also have long-term effects on rural development through contributing to enhance non-farm rural output and employment. As farm income rises and food prices fall, expenditure on non-food products increases boosting the growth of non-agricultural goods and services such as transportation, construction and agro-food industry, further generating employment and enhancing development (Lipton *et al.* 2003).

However, attention must be illustrated to the fact that these positive effects can be eroded or even reversed if irrigation services decline, or if schemes are expanded into unsuitable areas. Corruption can greatly increase uncertainty about the reliability of the service and can cause bad management and maintenance. Increasing the outreach of irrigation canals without the presence if enough irrigation water may cause conflicts between upstream and downstream farmers due to water shortage (Lipton *et al.* 2003).

In addition, irrigation has some social, health, and environmental consequences that are worth mentioning. Forced population displacement caused by dam construction is a serious counter-development consequence. Enough attention should be made, however, to the non-irrigation scenario so that the positive economic and social impacts of large-scale irrigation projects are not devaluated (IFAD 2001). Large-scale irrigation projects may also have some negative health consequences since they may encourage water-related diseases if inadequate drainage is in place. However, in dry areas, such projects may have contributed to the improvement of healthy conditions through enhancing green landscape and moderating high temperatures. But such projects, on the other hand, may cause losses in natural habitats that have an environmental value extremely difficult to assess (Cernea 1997).

Furthermore, when groundwater is used for irrigation by extracting water using pump sets, uncontrolled extraction and unorganised digging of wells may cause serious environmental problems manifested by lowering underground water table and increases water salinity consequently, as the case in AKB in the north-east of Syria (Sadiddin 2009).

The above-mentioned limitations raise the importance of the sustainability of irrigation policies pursued in many developing countries. Short-term benefits may be partially or totally offset by constraints and limitations in the long-term that may result from various political, institutional, environmental and social factors, some of which may limit an effective performance of irrigation, while others may be a consequence of weakly planned irrigation promotion policy.

1.2.2. Irrigation water provision: institutions and policy

Irrigation water represents a fundamental constraint on production especially in dry areas. Thus its allocation among individuals and communities is an essential matter that affects both production efficiency and social equity. Due to the public good characteristics of water, market forces cannot be relied upon to perform the function of its efficient allocation to various uses and users. In addition, the fact that rain water is a gift of nature, there may be strong social, cultural and religious objections to the idea of paying for water. When market fails, some alternative institutions must be found to ration the use of this scarce resource efficiently and equitably (Upton 2004).

The most widely institutional arrangements for the provision of irrigation water can be classified under individual acquisition, community allocation and bureaucratic allocation. The first is usually achieved directly by extracting water from a private well, but it can also be done by drawing water from a river or a dam located nearby, or through a contractual arrangement with a water supplier. Community allocation of water is currently rare and is performed by sharing the water of a communal source such as a village tank or well among the community users. Bureaucratic allocation is the most used method for large-scale irrigation projects, in which administrators are usually separate from users, and they mostly operate as public servants (Upton 2004).

Large-scale irrigation projects are usually the result of huge public investments in the construction of dams and irrigation canals to store and transport water, while tube-well irrigation projects are primarily a private business although they can be heavily affected by public policy through credit provision and institutional facilities. Ellis (1992) emphasises further the links between irrigation policy and other agricultural policies. He states that irrigation policy is linked to credit and input policy through increased working capital requirements of irrigated crops especially for the purchase of physical inputs that are complimentary to increased water use. It is linked to mechanisation policy as it entails some of the same issues of irrigation technology choice. It is also linked to price and marketing policies as farmers become with irrigation more price responsive and the necessity of a market infrastructure increases to handle the increased marketable surplus. Research policy can also be affected by expanding irrigation since priority of research is likely to be on irrigated cropping.

The objective of large-scale public irrigation projects and the promotion of private investments in tube-well irrigation has been to steer regional and national development via the participation of considerable proportion of people in direct and indirect benefits of such projects. This objective was behind justifying the construction of huge hydraulic infrastructures and, including dams and networks financed mostly by national governments at substantial costs. Such reasoning that can be called 'supply management approach' was, al least in part, caused by an optimistic view about the availability of water resources, and therefore the target was mainly to create investments that facilitate access to irrigation water by the largest portion of farming community (FAO & IFAD 2006).

However, performance of public irrigation problems started to emerge from the 1960s when it was observed that water was not enough to irrigate all irrigation areas and that increased crop yields were much below expectations. Later in the seventies, maintenance problems became substantial and rehabilitation was repeatedly necessary. Salination problems started to appear in some areas and returns became lower than before, and so benefits to the poor were lower than projected when calling for public funding and support. In some areas, total available resources started to decline and it was clearly manifested in hydraulic deficits in many water basins around the world due to excessive use especially from private tube-well irrigation projects. This has been further causing falling economic rate of return, which, in turn, has led to a decline in public irrigation investments (Lipton *et al.* 2003).

However, Lipton *et al.* (2003) argue that the decline in economic rate of return of irrigation investment is caused also by other factors including decreasing agricultural prices and some technical reasons. He argues that higher return projects are built first leaving less suitable areas for later. Rising construction costs is maybe another reason, especially when coupled with difficulties in costs recovery as the case with most irrigation projects. Poorly targeted subsidies and incentives and inappropriate water charging may also have played a role. Increased concerns about potential environmental consequences of irrigation projects, from which excessive use of water is only one, may have has created some adverse publicity and weakened political support for such projects.

The above-mentioned problems have caused over time a fundamental change in the way irrigation water resources had been organised and managed. The move from supply management approach to demand management strategies was caused by problems associated with finding the most efficient and equitable instruments and institutions to allocate the limited quantity of irrigation water scarce resources. These problems range from the appropriate institutional set-up that entails the role of different stakeholders (farming communities, irrigation administration institutions, public agencies, etc) to the appropriate charging method that maintain the resource sustainability from one side and ensure fair allocation of the resource among potential users and sectors.

Carces-Restrepo *et al.* (2007) discuss the possibility of irrigation management transfer as a possible tool for efficient management of water resources. It entails the transfer of responsibility and authority for management of irrigation systems from public agencies to private-sector organizations that are meant to represent the interests of water users. They define a number of rationales for this approach that can be summarised by: reduced burden of cost that governments usually face, expected improvements in the agricultural productivity and economic profitability of irrigation systems since this is the core concern of farmers (whereas it may not be an essential concern of bureaucracies), increased motivation of farmers to pay more for their irrigation system because they will be empowered to take over the authority, and improved accountability of irrigation system management to farmers producing more efficient and equitable water delivery and improved canal maintenance. However, at the beginning, such approach may increase the cost of irrigation for farmers, but the approach is expected to enable farmer's organizations to impose more cost-effective measures and that over time the productivity of systems will increase more than their costs.

However, Cornish *et al.* (2004) argue that irrigation management transfer does not inevitably guarantee recovery of full supply costs. Whilst turnover often results in an increase in levels of cost recovery, revenues are still generally insufficient to cover full supply costs, as tariffs are set too low mainly due to political pressure. Some irrigation management transfer policies reveal that recovery of water charges continues to be a problem after management transfer as many transferred schemes are struggling to enforce fee collection. This implies that governments' support for transfer should not be terminated immediately following transfer. Institutional, rather than financial, support is likely to be needed for some time after the transfer has taken place.

Cornish *et al.* (2004) primarily discuss the claims concerning irrigation water charging as a tool for achieving financial sustainability and water resource sustainability of irrigation systems. They argue that appropriate water charging instruments should be defined according to the objectives to be achieved. In the literature, considerable attention is devoted to the theoretical role of economic instruments (pricing and markets) to encourage productive use and optimal allocation. Acceptance of the rationale for recovering ongoing costs is almost universal (even if implementation is not). Full or partial recovery of investment costs is more controversial because irrigation is often seen as development expenditure for backward areas, benefiting not only the poor farmers but also society more generally through lower food prices and food security. Where these costs are not recovered, governments pay the difference or the infrastructure deteriorates.

Carruthers (1996), however, distinguishes between 'cost recovery' and 'irrigation financing'. Under the first, all funds collected go to the government treasury. Under the second, funds are retained within the irrigation agency to meet organisation and maintenance costs. This distinction is another way of underlining the need to go beyond the calculation of the level of cost to be recovered and making explicit the way in which funds raised are used to benefit the irrigation department or the individual scheme. Carruthers (1996) thus concludes that beneficiaries should pay the full ongoing costs of the irrigation system and that the payments should be clearly designated for use by the operating agency, and accounting procedures should be transparent and encourage efficiency in the operating agency. The extent and form of capital cost recovery for original investments is then a political matter that also should be open and transparent.

Ray (2002), on the other hand, emphasizes that irrigation departments in many countries need to improve the organization and maintenance of the main canal system and that incentives for their staff to operate efficiently are necessary. Water charging can accelerate this process.

Furthermore, it is argued widely that low water charges in a water-scarce situation send the wrong signal to farmers. Where charges are not linked directly to the volume of water used, e.g. where charges are fixed per hectare of crop, even if overall charges are high, there is no incentive to decrease consumption at the margin. However, the problem of setting the 'right' price remain a complicated issue since there may be a need to set the price at a too high level that many farmers cannot afford. In such cases, a rising block tariff, where some water is available at a low unit price and additional water at progressively higher prices, may be a sound solution. However, monitoring and record keeping are inevitably complex and costly, and if the price is incorrectly set, the demand may still exceed supply. The solution to this is usually to set a volumetric quota, below which charging is volumetric or on a rising block basis. However, if then appropriate water allocation and demand management are being achieved without reference to prices, the expense and complexity of pursuing pricing should be questioned (Cornish *et al.* 2004).

Available literature identifies a number of theoretical objectives of irrigation water pricing such as cost recovery, improving the service delivery, increasing efficiency, allocation to highest priority users, improving water quality, etc. However, in practice, just two objectives are dominant: achieving cost recovery and causing some reduction in irrigation consumption. The target level of cost recovery, or the magnitude of any reduction in consumption, varies between schemes and countries. Some commentators suggest that these two objectives may be combined and addressed through a single approach. However, it is unlikely that the two objectives will coincide precisely, so that additional measures may be required (Cornish *et al.* 2004).

Under the commonly used area-based charging systems, farmers pay a fixed fee per unit of land, assessed either on the basis of their total holding, the irrigated part of it or the actual crops irrigated. The system is relatively easy to manage, but is open to misuse, particularly through collusion between farmers and assessors to reduce the scale of the charge. Assessment based on irrigated area would appear to be the fairer method, but it requires considerable resources and effort. However, due to its relative easiness in terms of implementation and monitoring, it is maybe superior to other charging systems if the objective is cost recovery or irrigation financing of large-scale irrigation systems. The best way to implement remain an open question that should be answered according to the practical constraints and problems faced in different localities and countries (Cornish *et al.* 2004).

Volumetric methods may be a good response if the objective is to reduce water use. However, the high costs associated with its implementation, coupled with complexity of installing large number of metering devices and the vulnerability of these devices to accidental and malicious damage, might make it infeasible in most developing countries. In some circumstances, as practised for example in China, measured volumes of water can be delivered to an intermediate point, e.g. a township or farmers' organization, giving farmers responsibility for distributing and charging for water. Systems of bulk volumetric charging and area-based charging to group members can then co-exist. However, due to the complications associated with rising block tariff pricing that make it uncommon in irrigation, particularly in the developing world, the duration of delivery may be adopted as a proxy for the volume passed if the flow of water is reasonably constant (Cornish *et al.* 2004).

In areas where most farmers extract irrigation water from private wells, volumetric pricing, coupled with credit policy that favours the adoption of modern irrigation methods may be a solution if the objective is to reduce water use. Ward (2000) believes that pricing water is a viable option for reducing consumption when combined with the introduction of modern irrigation techniques. He stresses that if water pricing motivates farmers to increase water use efficiency, they will be more likely to adopt water-saving technologies, so investments and research in water conservation techniques would complement water pricing if they are supported from governments and donors. The emphasis of combining the adoption of improved irrigation techniques with water pricing is justified by the fact that, in many cases, modern irrigation was not enough to raise the awareness of farmers about the scarcity of water resource. Although, in many situations, these methods have caused increased yields, water saving was much below expectations (NAPC 2005a). Huppert and Urban (1999) also reports that the adoption of drip irrigation by many farmers in Jordan Valley has not caused significant reduction in water used since many farmers are aware of the unreliability of supply, and they tend to over-irrigated through their drip systems whenever water is available cancelling any potential for noticeable water savings.

Varela-Ortega *et al.* (1998) finds that the adoption improved irrigation technologies in Spain does not depend significantly on water price level but on structural factors, agronomic conditions and financial constraints. The latter constraints emphasizes the role of credit policy which should be favourable especially in developing countries where farmers have binding financial constraints as demonstrated by a case study in Syria (NAPC 2005a). Structural and agronomic constraints stress the importance of research to improving the current technology so it can overcome these constraints.

Caswell and Zilberman (1986) demonstrate that the probability of adopting drip irrigation technologies increases with higher water prices, although land quality and environmental constraints seem to play a greater role in technology choice, which again stresses the importance of research to overcome such constraints.

Therefore, appropriate measures to deal with sustainable use of water resources should be based on the specific conditions governing water availability and provision, which determine usually the objectives to be achieved. Different objectives require different measures, but water accessibility and water rights are also of high importance. We have seen that many of the measures prescribed to deal with large-scale irrigation systems do not simply apply if water is extracted from private tube-wells. In many cases, the institutional problems must be clarified before policy measures are introduced if they are to have any success.

A final note is that reduction in water use can be achieved also by the introduction or the promotion of crops that have low irrigation requirements. Governments may promote such crops directly through output price policy aiming to stabilize their prices or indirectly through promoting their demand, for example, via promoting their exports. In some critical cases of hydraulic deficit, changing the cropping patterns seems inevitable if water deficit is to be restored. Varela-Ortega & Sagardoy (2001) find that in AKB in Syria, even if all farms convert to modern irrigation, there will still be a considerable water deficit.

De Fraiture et al. (2004) states that trade may play a role in saving water. They refer to 'virtual water' as the volume of water used to produce traded crops, and so by importing food a Country saves the water it would have required to produce it. Therefore, water short countries should import food from water abundant countries. The concept of traded 'virtual water, although far from being practical, is insightful since it refers to the concept of water productivity, which may be a better measure of productivity than land in countries where water is the most limited resource, a concept in line with the conventional Comparative Advantage Theory.

1.3. Review of economics literature on decision making under uncertainty

Due to complex economic and physical systems, explaining the processes that are relevant to us cannot be revealed with perfect accuracy. The direct implication of this uncertainty in economic analysis is that any selected economic decision may have several possible outcomes, which characterise economic decision making by risk since not all outcomes may have the same value. Although certainty and risk are embedded in all economic activities, they can be considered an essential characteristic of agriculture (Moschini & Hennessy 2001).

One important concept embedded in economic modelling and analysis is that of optimization, which is usually coupled with a set of constraints when applied in modelling the behaviour of agricultural producers. The application of this concept raises a problematic question when risk and uncertainty are considered. This question involves the definition of what is really to be optimised. Although an answer acceptable to all is still far from being reached, there exists a wide consensus that economic agents subject to risk and uncertainty maximise expected utility (Moschini & Hennessy 2001).

In this section, we review the most widely used methods in economic analysis that suite the objectives of this research. The aim of the review is to provide the justifications and rationales lying behind the choice of analytical method used in this thesis, which is the use of mathematical programming for modelling the behaviour of agricultural producers taking into account the presence of risk and uncertainty. The model as described below applies the Expected Utility Theory through the mean-variance approach.

1.3.1. Qualitative analysis versus quantitative models

At the beginning of the study, we faced a fundamental problem regarding the methodology to be used to perform the analysis. Methods of research in economics, as in many other social sciences, can be basically classified under two general approaches: qualitative and quantitative. And the choice of one approach over the other depends on many factors, among which the most important is the objective of the analysis. While quantitative analysis requires mathematical or econometric models that need quite large amounts of data, qualitative research is generally done in the form of focus groups that enable the researcher to carry on group discussions.

Qualitative research has several advantages over the quantitative one. It allows the researcher to interact with the respondents, so that she can ask questions based on previous answers, which allows her to deeply understand the issues and yield great detail in responses. It also allows for interaction between group members. Such interaction often stimulates discussion and uncovers issues unanticipated by the researcher. Therefore, qualitative research is very useful to generate ideas and concepts, to uncover the farmers' reasoning process so it becomes possible to ask the right questions in the way they most accurately understand. It also allows the measurements of changes in policy and weather parameters on the group of farmers being interviewed, which may give some insights to the impact of such changes at some regional level and maybe at the national level.

However, as the group of farmers interviewed is small and far from being statistically representative of the farming community in question, qualitative analysis fails to aggregate the results to any regional level with a reasonable degree of precision. Therefore, it cannot examine many pre-existing ideas about the performance of farming sector due to its limited ability to quantify the outputs and inputs embedded in the process of production, which is of vital relevance to the objectives of this thesis.

1.3.2. Econometric models versus mathematical programming models

Having decided to use a quantitative approach, two general methods were initially considered: an econometric model based on time-series data and a structural mathematical programming model based on cross-sectional data. The decision has been made to use the latter for a number of reasons that are summarised below.

Econometric models can be usually used to estimate the supply and demand functions, which indicate the market equilibriums of quantities (supplied and demanded) and prices, which are then used to understand the way the sector tends to move. Supply functions of agricultural output estimated using econometric models can be quite useful in understanding the overall behaviour of the agricultural sector and sub-sectors. However, there are quite difficult problems to overcome when relying on such models, which can be generally categorised under the headings of data problems, economic structural changes (that may result from a policy change or external shock), or a combination of the two (Hazell & Norton 1986).

One important aspect of data problems arise from the fact that, in many cases, many crops compete for the available fixed resources employed in the production activities. This competition results in cross effects among the supplies of the different crops, which must be considered as necessary elements of the estimated supply functions of the crops in question. This poses the question of the necessity of having sufficient degrees of freedom in the time-series data used to estimate both the own and cross-price elasticities, which is usually difficult to obtain (Hazell & Norton 1986). This is very much true for developing countries such Syria, where data of this type, if they exist, are either scarce or quite imprecise.

Economic structural changes are usually caused by changes in the production technologies, market opportunities, and/or prices of both inputs and outputs. Government policies affect all of these. When using econometric models to analyse the current and alternative policy options, policy instruments may have to deal with values that are placed outside the values observed historically. In other words, it may be impossible to base policy analysis on extrapolations from parameters drawn from historical data when the policy instruments considered are new (Hazell & Norton 1986).

Mathematical programming models can assist sufficiently to solve both problems, since they are based on cross-sectional farm budget data and other information obtained at the micro level to generate optimal cropping mixes and individual supply functions. In addition, they can be used to analyse the direct changes in economic structure whether related to change in technology, which usually affects yield and production costs, or related to prices and market opportunities, which change the profitability of various activities. This is due to the fact that cross-sectional data, because of their detail, allow for a relatively precise specification of farm technology and for the introduction of new crops in the analysis if the technical coefficients of such crops are available with an acceptable level of precision (Hazell & Norton 1986).

Such changes and their effects are very difficult to capture through econometric models, which means that the resulting estimates of supply elasticities of such models are unreliable when such structural changes are introduced into the model. Furthermore, the supply functions of programming models provide plenty of information useful to estimate the derived demand functions of inputs, which allows tracing the impact of policy changes not only on the outputs, but also on the derived demands of agricultural inputs such as labour and water (which is of great relevance in our thesis). Moreover, the opportunity cost of limiting resources may be assessed from the shadow prices associated with each constraint (Hazell & Norton 1986).

Moreover, the use of econometric models requires some assumptions that are difficult to be made for the main agricultural commodities in Syria. They are the assumptions of competitive markets, which do not hold for many crops in Syria especially the so-called strategic crops. This is because these crops have fixed prices (cotton, sugar beet and tobacco) or floor prices (wheat, barley, chickpea, and lentil). These prices are for many crops maintained at levels higher than their international counterparts (e.g. prices of cotton, wheat and sugar beet). In addition, the cultivation of some of these crops (cotton, sugar beet and tobacco) is organised through a licensing system that further violates the assumptions of competitive markets.

Therefore, it seems that mathematical programming models may be a better approach for the analysing the impact of policy changes on the agricultural sector of a small region. Combining the mathematical programming with representative farm approach reduces significantly the amount of data needed and assists in representing the cross-effects that may be present in the agricultural sector of the region in question. Representative farm-level models are also useful because the outcomes of any policy depend on how individual farmers react to policy-influenced environment. Even if policy is designed at a national level, its outcomes differ according to the structure and localisation of farms. Thus farm representation allows measuring the impact of alternative policies on different farm types separately since representative farms' classification may be performed according to their resource endowments, technology used, etc. If farms' locations are considered, the power of this method is extended to measure the aggregate impact on specific regions, which is becoming an important issues as policy makers are increasingly interested in the regional or sub-sectoral impacts of alternative policies (Buysse *et al.* 2007).

This does not mean, of course, that mathematical programming is without problems. The choice of the objective function and the representation of relevant constraints may have great consequences on the results. While the choice of the objective function to be optimised will be discussed in the next section, we will leave the choice of relevant constraints to Chapter 3, which is basically concerned with the empirical model used in this thesis.

1.3.3. From profit maximization to expected utility maximization

Farmers' decisions are usually made subject to their physical and financial constraints and in the face of considerable uncertainty, which may arise from variations in yields and/or prices and from policy changes as well. Mathematical programming models have been repeatedly used by policy analysts in order to model farmers' decisions, so that they can then be used to predict what farmers may do if a policy parameter is changed. They also can assist in predicting the impact of a policy change on the sector performance when they are coupled with farm representative approach (Hazell & Norton 1986).

In much applied research, the simplest form of programming models has been repeatedly used, mainly for its simplicity as a method of determining a profit maximising combination of feasible farm activities (i.e. a linear objective function) subject to a set of resource and technology constraints. Such models assume profit maximisation behaviour in a certain environment, which means that farmers do maximise profits and they perfectly know the input-output relationships and prices of inputs and outputs, which are assumed to be fixed in such models (Hazell & Norton 1986).

The use of programming models in policy analysis entails that such models in their reference run must replicate the observed reference situation as much as possible, which is usually taken to be the observed cropping mixes. In other words, the cropping mixes produced by the model must be close enough to those observed ones in the reference year or period. This is important since policy makers are interested in the comparison between the current policy impact and the impact of alternative policy actions (Buysse *et al.* 2007). However, the need to simplify such model to keep them analytically tractable has always contributed to the fact that when the model solutions are confronted with the observed cropping mixes, the former are usually characterised by a high degree of specialisation with respect to the latter. This matter prevents the use of such models in the simulation of alternative policies, since there is no guarantee that their predictions are reliable when their first run solutions are very different from the observed behaviour (Cafiero 2004).

Buysse *et al.* (2007) present in details, using graphical analysis, the implications and consequences of the models' simplification. They demonstrate that the main disadvantages of such models are their 'rigidity' and 'jumpy behaviour'. By the first, they mean that, in standard linear programming models, small changes in the model parameters do not change the optimal solutions, while only large changes do. However, these large changes in the model parameters result in large changes in the optimal solutions too, and this is what is meant by 'jumpy behaviour'. This is the most challenging issue for the modeller, since, in many case it is impossible to validate the model on the observed behaviour without adding more information or assumptions, whether they are technical or behavioural.

To overcome this shortcoming, several calibration procedures have been developed that resort to modify the model structure so that the model solution coincide with observed behaviour. The most widely applied calibration procedure is the so-called Positive Mathematical Programming (PMP), which was first presented in its standard form by Howitt (1995). He argues that, at a regional level, data on production levels and farm land uses are more precise than the estimates of marginal costs of the farms' crop production. Therefore, PMP uses the observed land allocation and production levels to infer the marginal costs for each crop allocation of land observed in the official data. He further argues that if the model does not correspond to observed cropping patterns with a set of linear constraints that can be empirically justified, a necessary condition is that the objective function is nonlinear in at least some of the activities. Then an exact calibration depends on the number of nonlinear terms that can be independently calibrated.

That is why Howitt (1995) argues that adjusting some nonlinear parameters, such as the risk aversion coefficient, although improves model calibration, cannot calibrate exactly. Therefore, there is the need of 'sufficient' independent nonlinear terms to calibrate precisely, in the sense that the number of nonlinear terms need to span the number of activities that must be calibrated.

The PMP is then based on two main assumptions: first, the observed situation represents the optimal solution for the modelled farms in the base year; second, there are hidden costs associated with each activity that cannot be directly observed by the modeller. Then the PMP calibration approach introduces the concept of decreasing marginal returns through incorporating nonlinear cost term in the objective function (Müller & Djannibekov 2009).

The standard PMP calibration procedure consists of two sequential stages. In the first stage, the model is solved as a linear programming model that maximises a linear profit function with additional 'observation' constraints that bind the model solution to replicate the observed cropping mixes. The dual values of the additional constraints are considered as the difference between price and marginal costs for the preferable activities are interpreted as the values that capture model's false specification, data measurements errors, aggregation bias, risk aversion behaviour, and price expectations. In the second stage, these dual values are used to construct a non-linear cost term, which forces the optimal solution to exactly replicate the observed behaviour without additional unrealistic and empirically unjustified constraints, meaning that the calibration constraints are omitted from the model in the second stage (Howitt 1995).

Following the above-described procedure, the PMP approach solves the jumpy behaviour and over-specialisation problems, while maintaining the model's flexibility and producing the exact observed behaviour.

However, as Cafiero (2004), argues this flexibility comes at the cost of imposing some assumptions that have weak scientific justifications. The PMP is based on the assumption of profit maximisation objective function, coupled with an assumed cost function such that, for each activity, the marginal cost equals the marginal revenue at the optimal solution. But the parameters of this cost function are determined thanks to the imposition of other two assumptions, which are: the marginal revenues of all activities are observed with certainty; and the marginal cost equals marginal revenue for all activities. Therefore, there is the risk that the mathematical model loses its structural characteristic since it is always possible to find a combination of parameters for the assumed cost function that allows the model to reproduce the observed behaviour, given sufficient flexibility in the functional form chosen for the cost function. Therefore, the PMP model is maybe correct if the profit maximisation assumption is reasonable, as been observed by Zilberman (1989) for the so-called dual models.

Given the above, it is may be complicated to interpret the dual values of the additional constraints. The interpretation provided by Howitt (1995) that they capture model's false specification, data measurements errors, aggregation bias, risk aversion behaviour, and price expectations does not seem to have a strong scientific basis as the effects of different issues are mixed together. Therefore, these values are really complicated to interpret.

In addition, and in line with Cafiero (2004), the PMP may be good when aggregate data of production and cropping areas are of high reliability. The first assumption that Howitt (1995) makes is that, at a regional level, data on production levels and farmland uses are more precise than the estimates of marginal costs of the farms' crop production. While this is maybe true in developed countries such the United States and the European Union, it is not necessarily the case in developing countries where data when exist experience considerable degree of flaw and inconsistency. Then when this approach is applied in a developing Country, the risk increases that modellers may, instead of looking for more reliable data to validate the model, rely on the 'automatic' calibration procedure that PMP approach provides.

Furthermore, Müller & Djannibekov (2009), who apply the PMP approach in calibrating the analytical model for the analysis of the agricultural sector of Khorezm (Uzbekistan), find that the additional cost terms are in many cases large and some very large that cannot be justified by any provided information whether from survey or from experts. As a response, they propose another calibration approach, which, although appears to be different from the standard PMP, has similar shortcomings. They instead modified the technical coefficients using a range derived from the available information in which they can assume any value; therefore, the calibration outcome is sensitive to any change in the selected values for the technical coefficients.

On final note about the calibration procedures discussed above is that the choice of the functional form of the objective function in the initial model affects all the subsequent stages of the calibration process. As Müller & Djannibekov (2009) admit, the calibration proposed is *ad hoc*, as it has been tested only for the specific case of a quadratic function. In the case of a linear function, the proposed approach would create different base solutions that would require different modifications in the technical coefficients to achieve exact calibration. A similar shortcoming can be said about the standard PMP as explained below.

Other potential shortcomings of the PMP are also reported in De Frahan *et al.* (2007) and are discussed together with the further developments in the PMP that are progressed to overcome the shortcomings. The development that is of interest to the aim of this review is the attempt of Paris to use a von Neumann-Morgenstern expected utility function instead of a linear profit function as in the standard PMP model. The objective is to integrate risk into the model structure explicitly through a combination of income variance and risk aversion coefficient (De Frahan *et al.* 2007). However, if the effect of risk, which usually implies price expectations, is captured already by the initial objective function, then following Howitt (1995) the dual values of the calibration constraints will represent data errors, aggregation bias and false specification of the model. But once again, there is no clear scientific basis to justify calibrating for all of them using a non-linear cost function based on the assumptions that there are costs unobserved by the modellers but are relevant for the farmers.

In addition, the choice of the functional form of the initial objective function changes the dual values of the calibration constraints which means that the non-linear cost function will be different too. In many cases, false specification of the model may be because many technical aspects of farm practices are ignored by the modellers due, e.g., to their weak agronomic backgrounds (Cafiero 2004). If this is the case, the modellers must instead look for more relevant information, which in turn, may solve the problem of data errors, while the problem of aggregation bias should be irrelevant if data on cropping areas and outputs are reliable as Howitt (1995) assumes, in the sense that its effects should be minimal.

For all of the above-discussed reasons and arguments, a different approach is adopted in this thesis to set up solve and validate the mathematical programming models used for the purpose of policy analysis in this thesis, to which we turn now the discussion.

As hinted above, the absence of uncertainty is too stringent of an assumption if we consider that risk is embedded in every economic activity, and that agricultural production is characterized by an unusually high degree of risk. This is due especially to its reliance on biological processes and its susceptibility to the vagaries of climate and weather. Added to this is the inelasticity in the supply of and demand for agricultural commodities, which can lead to large price fluctuations in agricultural markets when harvests are exceptionally bad or good. As a consequence, farmers exposed to uncertainty will usually fail to maximize profits since they are uncertain about the outcomes of their decisions at the moment they make them. This leads us to believe that a better modelling assumption is that farmers do not maximise profits, but rather they attempt to do so, given the available information, technology and states of nature, by balancing the possibility of negative outcomes due to the presence of various sources of risk.

Many studies have demonstrated that farmers typically behave in risk-averse ways. They show that farmers generally prefer farm plans that provide a certain level of security even if this implies scarifying income on average. Such plans involve that riskier activities produced less, compared to how they would be if there were no uncertainty. Farmers also tend to reduce risk by diversifying into a larger number of activities. Therefore, ignoring risk and uncertainty in farm modelling leads often to results that are far different from the plans that farmers follow in reality (Hazel & Norton 1986).

In the presence of risk and uncertainty, a farm plan does not generate a known income every year; it rather may generates several possible levels of income depending on the materialised values of yields, prices, and resource availabilities. In this context, one can think of the farm plan as having a probability distribution for income, and if the number of possible outcomes is finite, we can arrange the decision problem in a form of payoff matrix, where every alternative farm plan will have different outcomes for different states of nature that reflect variation in yields, prices and resource availabilities.

Many alternative methods have been developed in economic literature to present ways of ranking incomes distribution. Most of them try to measure income variability to give a measurement of risk, although some are more quantifiable than others. The most established decision theory in economics is the Expected Utility Theory (Bernoulli Principle). The theory that was developed by Von Neuman & Morgenstern (1944) is based on a set of reasonable axioms about how an individual ought to order risky prospects, these axioms can be summarised as follows:

1. Ordering: any decision maker when faced with two risky prospects, a_1 anda_2, he will either prefer one to another or will be indifferent between them.

2. Transitivity: if the decision maker prefers a_1 to a_2 (or is indifferent between them), and she prefers a_2 to a_3 (or is indifferent between them), she will then prefer a_1 to a_3 (or will be indifferent between them).
3. Continuity: if a decision maker prefers a_1 to a_2 and a_2 to a_3, then there exists a subjective probability $p(a_1)$, which is not zero or one, that makes the decision maker indifferent to a_2 and a lottery yielding a_1 with probability $p(a_1)$ and a_3 with probability 1 - $p(a_1)$.
4. Independence: if a decision maker prefers a_1 to a_2 and a_3 is any other risky prospect, she will prefer a lottery yielding a_1 and a_3 as outcomes to a lottery yielding a_2 and a_3 when $p(a_1) = p(a_2)$ (Hardaker *et al.* 2004).

The fulfilment of the behavioural axioms of the theory does not restrict the utility function of the decision maker to any particular functional form, and so a functional form can be chosen that best describe the decision maker's behaviour. In addition, since the theory predicts that risky prospects will be ranked by their expected utility, the choice of the functional form of the utility will have consequences on the determination of the risk preferences of the decision maker. Therefore, the fundamental problem facing the analyst is to choose the functional form that best describes farmers' behaviour. In some cases, the utility function can be measured by playing a series of carefully designed gambles with a farmer, and then a regression can be used to find the fitting functional form. However, such elicitation of utility functions is not always practical especially when dealing with a large number of farmers. So many analysts simply assume a functional form that is computationally convenient. Then when some of the function's parameters are unknown, the farm model can be solved several times for alternative parameter values and the ones that give the closest solution to the farm actual plan are selected (Hazell & Norton 1986).

The most widely used method for the employment of expected utility principle in applied economic research is the Mean-Variance Analysis. The mean-variance rule presumes that the preferences of a farmer among various possible plans are based on expected income and its associated variance. This decision rule results from the expected utility theory if the decision maker has a quadratic utility function for income. However, quadratic functions are characterised by increasing absolute risk aversion violating an important element of risk aversion theory which states that absolute risk aversion declines as income level goes up. An alternative derivation of the mean-variance rule comes out if the utility function is of the exponential form:

$$U(Y) = 1 - e^{-\beta y} \qquad [1.1]$$

Where the income (y) is normally distributed.

Under such circumstances the objective function to be maximised is the one proposed by Freund (1956) which is:

$$E(U(y)) = E(y) - 0.5\beta Var(y) \qquad [1.2]$$

Where β is the absolute risk aversion coefficient.

The evidence of equation [1.2] to be a good approximate of equation (1.1) is investigated by Pulley (1983) who shows that, given the data used, approximations are very good and in many cases the optimal solutions were identical.

In line with equation [1.2], Hardaker *et al.* (2004) propose using certainty equivalents of the alternative risky prospects instead of expected utility values, since they are more easily understood and interpreted, as the magnitudes of their differences between alternatives can be quantitatively assessed, while the arbitrary nature of utility scales means that it is impossible to weigh one utility value against the other. Consequently, equation [1.2] is replaced by the following equation:

$$CE = E(y) - 0.5\beta V(y) \qquad [1:3]$$

Where *CE* is the certainty equivalent which is the quantitative measure proposed to quantify expected utility of income. In this case, the second term of the equation's left-hand side represents the risk premium.

However, our choice of the functional form of the objective function, although has some scientific basis in economic theory, does not by itself guarantee that the model is accurate. The optimal solution in our model depends on the average income, the income variance, and the value of the risk aversion coefficient (RAC). While the first two terms are calculated from the matrixes of technical coefficients and of that of prices, the third is assumed as an exogenous parameter that measures the degrees of risk aversion of different farmers. These different degrees of risk aversion are maybe due to differences in the initial endowments, the level of wealth, and other entitlements that they enjoy when they face various risky choices. In our case, RAC is assumed to take the value for which the optimal solution gives cropping mixes as close as possible to the observed ones. However, due to reasons well explained by Howitt (1995), adjusting RAC improves model representation of the observed reality, but cannot calibrate exactly.

However, the interest of this thesis is to measure the impact of alternative policies on water on an aggregate level, which is what is relevant to policy-makers. Then what is necessary is that the cropping patterns and agricultural water consumption produced by the model are close enough to those observed at the relevant aggregate level. The impact on incomes is also measured at an aggregate level which is a weakness of this thesis, since policy makers may be interested in knowing the distributional effects and not only the aggregate one on farmers' incomes, which is maybe a shortcoming of our model. However, in order to overcome this shortcoming, we use some statistical measures, namely the coefficient of variation, to have some insight on the distributional effects within each governorate.

To improve the model flexibility, a very necessary property when making policy simulations, we set up the models using as much data as possible. All available data are considered, whether they are given at higher or lower levels of aggregation. In addition, many of this data are crosschecked using data collected at the farm levels, some of which were collected for other studies while others were gathered for the sake of this research. Due to time constraints, several assumptions were adopted on the basis of interviews with key informants and experts, all of them were also crosschecked with each other and with opinions of farmers to gain insights about their plausibility. The model detailed characteristics and the data used are extensively described in Chapter 3 and no need to repeat everything here.

1.3.4. Limitations of the Expected Utility Theory (EUT)

The aim of this section is to discuss the limitations of the Expected Utility Theory (EUT) in light of the most important economic literature on decision-making and choice under risk and uncertainty. This is a vital issue to define the degree of reliability of the mathematical programming models based on EUT, as the one used in this thesis.

Empirical research that dates back to the fifties has revealed a number of choice behaviours that appear to violate some of the EUT's axioms listed in the previous section. Starmber (2000) classifies these violations under two broad headings: those that have some explanations in the conventional theory of preferences, which primarily violate the independence axiom; and those that do not, which usually violate one or more of the other three axioms; that is to say they challenge the assumption of well-defined preferences.

In response to these findings, many other models, which all have a common aim of providing some improvements on the standard von Neumann-Morgenstern expected utility model particularly, try to model the abnormalities that seem to violate one or more of the axioms of the EUT. Starmer (2000) demonstrates that people may violate the EUT maximisation for two broad reasons: failure of preferences due to the dependence of the utility of outcomes on the particular risky prospects faced by the decision maker and failure of perception i.e. to make well-defined preferences. Models that modify the outcome weightings departing from a standard utility function have been used to address failure of preferences, while models that modify the probability weighting are developed to address the failure of perception.

Kahneman & Tversky (1979) present one of the most important critiques to the EUT when used as a descriptive model of decision-making under uncertainty. They argue that choices among risky prospects reveal several effects that are inconsistent with of the EUT. For example, people underweight outcomes merely probable in comparison with outcomes obtained with certainty. This tendency contributes to risk aversion in choices involving sure gains and to risk seeking in choices involving sure losses. They argue, in addition, that people generally disregard components shared by all prospects considered, leading to inconsistent preferences when the same choice is presented in different forms. Therefore, they develop another theory of choice and they call it *prospect theory*, in which value is assigned to gains and losses rather than to final assets, and probabilities are replaced by decision weights.

Quiggin (1982) design a new model and call it *anticipated utility* (it was later called the *rank-dependent expected utility model*) to explain the observation that many people purchase lottery tickets, which is an action implying risk-seeking, but they also buy insurance, which implies risk-aversion. He argues that people overweight low-probability events such as winning the lottery or suffering disastrous loss. The basic idea of the rank-dependent model is to overweight the unlikely extreme outcomes rather than all unlikely events, which was then incorporated by Kahneman & Tversky (1992) to yield their new *cumulative prospect theory*.

Chambers & Quiggin (2000), who first presented the *state-contingent approach* to production under uncertainty, claim that aforementioned approach provides the best way to think about problems in the economics of uncertainty, including consumer's problems, producer's problems and principal-agent relationships. The theory provides a new basis for deriving optimality criteria under uncertainty, using the concept of stochastic production function in which output is derived from the interaction of inputs with natural phenomena and then it depends not only on the level of inputs used but also on the 'state of nature' that prevails.

Rasmussen (2003) extends the state-contingent approach and applies it for risk-averse producers. He finds that it is not possible to derive criteria of optimality for strictly risk-averse producers, but useful criteria are derived for risk-neutral producers. In this respect, he finds that, given the state of nature, risk-averse producers may use more or less inputs than risk-averse producers do, a finding that contradicts the expected utility predictions, which state that risk-aversion causes suboptimal use of physical inputs.

However, Rasmussen (2006) states that applications of the criteria derived from the state-contingent approach require that production functions are known. Since most empirical work concerning optimizing production under uncertainty is historically based on the standard EUT, the approach based on the state-contingent approach carries new challenges with respect to both modelling utility and the choice of functional forms and procedures for estimating state-contingent production functions. He also states that it is unrealistic to expect that production functions can be estimated for all possible states of nature, and indeed state-contingent production functions may be estimated for only a few states of nature. The main conclusion concerning empirics is that when this is the case, each of the state-contingent production functions available should be considered a stochastic production function.

Rabin (2000) extends the critique to the standard EUT by demonstrating that the latter is unable to provide a plausible account of risk aversion over modest stakes, even though it provides a reasonable explanation to risk behaviour regarding relatively large-scale financial risks. The latter is justified by the fact that the marginal value of an additional dollar to a poor person is more worthy than for a wealthy person. Rabin (2000) uses the concept of loss aversion, first introduced by Kahneman and Tversky (1979) in their prospect theory, to explain risk aversion over modest stakes. Loss aversion means that people define their utilities by changes in wealth rather than by their obsolete levels.

Just and Pope (2003), on the other hand, argue that risk aversion has been overestimated in most economic literature, in which many practices and procedures pursued by farmers and individuals are interpreted as consequences of risk aversion while it is not necessarily the case. They argue that risk attitudes may rather be the consequence of other phenomena and constraints such as fixed allocated inputs, asset fixity, imperfect capital markets, inter-temporal financial management, possible bankruptcy, etc.

To sum up this discussion, it is clear that the EUT does not fully explain decision-making under risk and uncertainty. However, it is reasonable to accept that people seek to comply with the EUT's axioms, given the information they have. People fail to keep in line with axioms due to perceptions failure and preference failure, but people try to approach them and that is why Hardaker *et. al* (2004) propose to use the EUT as a perspective tool rather a descriptive tool.

In addition, the alternative models, although they have better theoretical predictability of decision-making, their applicability in research is very limited due to their huge data requirements as hinted by Rasmussen (2006). This is especially true when the purpose is to trace the policy impact of a large number of farmers. Therefore, our choice of selecting the mean-variance principle as an approximation of the EUT is constrained by the types of data available, since data to apply, e.g., the state-contingent approach are huge and impossible to obtain. In addition, Just & Just (2009) demonstrate that the EUT hypothesis cannot be rejected because perceptions and preferences, which both affect behaviour under risk, cannot be measured separately. Therefore, all alternative models cannot achieve empirical superiority to the EUT since they do not admit errors in perception and probability. They instead propose a practical approach that combines both perceptions and preferences through a mean-variance (they call it also a *mean-risk premium*) criterion which is almost what we apply in this thesis.

Furthermore, one of the critiques against the standard EUT makes the latter more applicable. The observation of Rabin (2003) that people utilities are determined by changes in their wealth rather than their absolute wealth is helpful in policy analysis, since it is always easier to measure changes in wealth rather than to measure the net wealth as data on initial wealth are more difficult to obtain.

1.4. Critical review of past studies on water use in Syrian agriculture

Although policy makers and analysts recognise water scarcity in Syria as a priority, the research literature is still relatively poor on how to guide the formation of effective alternative water policy.

Safi (2006) and Somi & Alshayeb (2002), focus on improving water use in Syria through converting the flood-irrigation to modern methods. Both reports present updated estimates of the existing water balance (a subtraction of water use from water availability) commenting to the possible effects of adopting the modern irrigation techniques.

However, Somi & Alshayeb (2002) performed some irrigation experiments on certain crops and use their results to compare the differences in terms of costs, profits, and water use between flood irrigation and modern methods. The study proves the superiority of modern techniques, not just in terms water saving, but also in terms of profits driven by increased yields. The data presented in the study, however, have been obtained in ideal experimental conditions that are very different from those under which actual Syrian farmers operate, which casts some doubt on their reliability as predictors of the actual impact of the diffusion of modern irrigation, a point made even stronger by the failure to present considerations related to aggregation of the results at any regional level in the Country.

Other relevant studies are Varela-Ortega & Sagardoy (2001) and NAPC (2005). These are different from the above-mentioned ones insomuch as their focus is on agricultural policy and its possible impact on water use.

Varela-Ortega & Sagardoy (2001) provides a detailed summary of available water resources in the Country, differentiated by source (rainfall, underground water, rivers, etc) and use (agricultural, industrial, domestic, etc). Then, water balance is calculated by observing the difference between water availability and uses. The data used in these calculations refers to the period 1999-2000, and they show that Syria experiences a high water deficit that accounted to 3,104 millions of CM in the period 1999-2000. An interesting point of the study is that the AKB had in that period a deficit of 3,105 millions of CMs, which is slightly higher than the national one (Varela-Ortega & Sagardoy 2001, p. 18). This emphasises the importance of the water problem in the region of the AKB.

The study simulates four scenarios to estimate the projected water demand with respect to different policy alternatives as follows:

- Irrigation expansion of a total area equal to 414,395 ha, 136,545 ha of which is in AKB, coupled with modernising irrigation over five years at a pace of 319,017 ha/year for entire Syria and 101,019 ha/year for AKB.
- A gradual modernisation where the total irrigated area (1,149,349 ha) is modernised over a period of 15 years at the rate of 80,000 ha/year, without any expansion of irrigated area.
- Same as the first scenario but the modernisation process is undertaken over the entire irrigated area at the rate of 80,000 ha/year, which is in line with some international experiences.
- The last scenario simulates different irrigation policies for the most critical basins. For AKB, all the irrigated area is modernised in 5 years and no new irrigation is developed.

The results of these scenarios regarding AKB suggests that the expansion of irrigation to new areas should be halted in order to achieve equilibrium between water demand and supply within the basin (the first scenario). The third scenario results in reducing the deficit in the first 11 years because the annual balance between the new modernised areas and the added ones is positive. However, the trend reverses after the eleventh year as all the existing irrigated areas are then modernised and only new areas are added.

The second and the forth scenarios suggest that even if the whole irrigated area is modernised either over a relatively long period (15 years as in the second scenario) or over a relatively short period (5 years as in the forth scenario), AKB will continue to experience a high deficit that will eventually lead to the depletion of water aquifers. Therefore, the study concludes that the irrigation modernisation is insufficient to restore the water balance in AKB, and there is a need for alternative measures, which may be:

- reducing the consumption per well
- closing some wells
- reducing the irrigated area
- limiting the cropping pattern to crops with relative small water requirements
- any combination of these measures

The study then proposes that the most suitable measures or the proper combination of them should be based on a deep investigation of the hydrological and water use characteristics that should be studied in details in order to assess different water policy alternatives. (Varela-Ortega and Sagardoy 2001, p. 20). The main strength of this study, as opposed to the previously mentioned ones, is its ability to aggregate the results to the regional and national levels, which allows making policy scenarios assessing the impact on water use of some alternative irrigation policies.

However, the study, as hinted by its authors, is limited to make scenarios concerning irrigation water policy only (that is modernising and expanding irrigated areas). It concludes that the adoption of modern irrigation schemes is not sufficient to restore the water balance in AKB and, therefore, suggests some other measures. Nevertheless, some of these measures must be taken into consideration with high degree of care even if they may be effective in solving the water deficit problem in the region. Closing wells may cause tension between farmers and the governmental agencies, and can impede further cooperation from the farmers' side to implement other policy measures such as reducing the consumption per well, which is, in turn, difficult to perform and monitor as it requires metering the wells. The same difficulty applies to limiting the irrigated areas and/or limiting the cropping patterns to crops that require less water unless these measures are implemented through providing economic incentives to farmers.

NAPC (2005), on the other hand, has the objectives of providing an updated picture of the current situation of the Syrian water sector in Syria, with emphasis on agriculture, to assess the impacts of the current and alternative economic incentives for farmers on water use. Namely, it aims at assessing profitability under different irrigation technologies (traditional flood versus modern ones: drip and sprinkler), to enable suggesting some policy options to cope with water scarcity and to achieve a sustainable water use, namely in agriculture. The study takes AKB case as considered the most critical basin in terms of water deficit.

The study findings demonstrate that the growing water deficit in Syria mainly results from the evolution of water supply, which has been almost constant since the early eighties, and of increasing demand in the last decades. Unsurprisingly, agriculture is the sector that demands the largest share of water, at national (79% of total uses) as well as at basin level (e.g. in AKB, agricultural use accounts for almost 95% of total use). This is obviously because agriculture is the largest economic sector in the Country but also because flood irrigation, characterised by low efficiency, is the dominant method. Furthermore, the difficulties in monitoring groundwater extraction cause a vicious circle of random wells' digging, leading to an overexploitation of underground water, reducing water tables, which, in turn motivates more random digging (NAPC 2005a, p. 75).

The study hints at possible technological, financial, and institutional problems that constrain farmers' decision to convert to modern irrigation. Technological problems are summarised in the low quality of plastic pipes available for adoption of modern irrigation schemes, which makes them rather short-lived, and thus less cost effective. Financial problems are caused by farmers' inability to access sufficient credit required to invest in modern irrigation techniques. The institutional problems are summarised by the fact that the Agricultural Cooperative Bank (ACB), which is the main governmental provider of credit to farmers in Syria, does not possess the required efficiency to timely and cost effectively provide the required funds to finance the conversion process as envisaged by the government plan. One of the problems with the ACB lending procedures is that it does not accept lands located within the perimeter of the public irrigation schemes as collaterals for irrigation loans, further limiting the ability of some farmers to access credit (NAPC 2005a, p. 76).

The study recommends some policies that favour the adoption of modern irrigation techniques by farmers by providing economic incentives on investments. The most important is the reduction of the interest rate on the loans offered by the ACB to fund the purchase of pumps and irrigation equipments (drips, sprinklers, pipes, etc.). It also proposes a direct subsidy on the cost of pump investment and on the cost of irrigation equipment investment. It recommends, as well, the provision of economic incentives on operation and maintenance in the form of a subsidy on the price of fuel to operate pump-sets (NAPC 2005a, P. 78). These recommendations were taken into high consideration by the Government of Syria (GOS) (refer to **section 2.2.1**)

The strength of this study is that it uses data collected at the farm level, reflecting the actual technical conditions under which farmers operate. This makes the results of the research in terms of water-saving coefficients and profitability more reliable than those of Somi & Alshayeb (2002), which uses data generated in experimental conditions, as noted before. However, the study only focuses on comparing the water use and profitability between different irrigation techniques at the farm level, and so it shares Somi *et al.* (2002) weakness of failure to aggregate the results to any regional level in the Country.

1.5. Critical review of past studies related to farm income risks in Syria

So far, risk and uncertainty have not been taken broadly into consideration in most researches and studies performed on Syrian agriculture. This has been the consequence of the prevailing economic system in the Country that has been based, for a long time, on central planning, in which Government involvement in the economy was intense. Such economic system, although proved expensive and inefficient to achieve the national objectives declared by the GOS, was able to isolate farmers from unfavourable conditions such as price shocks and fluctuations. However, as the Government started in the early nineties a programme of economic reform by giving more space to the private sector and moving to 'indicative' planning in agriculture, increased attention started to be given to risk and uncertainty and their impact on the stability of agricultural incomes.

Several studies have been recently performed in Syria to inform the policy decision-making at this crossroads of Syria's agricultural history. These studies cover the analysis of risks, opportunities and policies in meeting these challenges while preserving the social achievements inherited from the past. Some of them cover some subsectors of Syrian agriculture while others focus on policy issues and constraints that obstacle the promotion of agricultural development in the Country. Westlake (2001) provides an analysis to the economics of the strategic crops' subsector with focus on efficiency and public losses, while the growth potentials of olive oil and citrus subsectors are explored by Malevolti (1999) and Westlake (2000) respectively. The livestock and dairy sub-sectors are also analysed along with their marketing arrangements by Cummins (2000) and Rama (2000). Other interesting studies have covered the implications of credit (Parthasarathy 2000: 2001) and taxation (Wehrheim 2001) policies on agricultural investments and developments, while Lançon (2005) analyses the potential comparative advantages of the most important crops and reveals that wheat and cotton, the most important strategic crops, do not have comparative advantage in many areas of the Country.

The focus and emphasis of all the above mentioned studies have been mostly on improving the efficiency of resource allocation and use when designing and implementing policies to achieve the national objectives declared by the Government. These objectives have been recently modified to reflect the changing environment and meet emerging challenges that are mostly the increased exposure to risks and uncertainty and exacerbated depletion of natural resources especially land and water. This has been reflected in the new National Agricultural Strategy by emphasising the role of preserving the scarce natural resources for sustainable development and the importance of protecting farms' incomes (NAPC 2006).

The only study, done so far, that explicitly attempts to discuss and analyse the various types of risks to which Syrian farmers are exposed is the Farming Systems Study conducted by the National Agricultural Policy Center (NAPC) and summarised in an impressive comprehensive report by Wattenbach (2006). The study considers the potential impacts of agricultural policy change at the household, regional and national levels. The study declares its specific objective as to divide the entire Country into relatively homogeneous zones of agricultural production, based on appropriate agro-ecological and socio-economic characteristics. The characterisation of each farming zone in the national context has allowed reviewing the possible aggregated effect of policy change as well as the dependence of each farming zone on major crops, which could be subject to policy adjustments.

Wattenbach (2006) relies on extensive fieldwork that permitted the classification of households in each farming zone into categories based on socio-economic characteristics. Past developments of each household category are recorded to define the resource endowments and the different income sources that shape the capacity of households to adjust to future challenges. In addition, the various types of risk, to which all household typologies are exposed, are defined in each zone, discussing in a detailed manner the relative magnitude of each type of risk for different zones and households. He also provides extensive information on the characteristics of the farming zones and the activities carried out by farmers in each of them. He demonstrates comprehensively the natural conditions, the market integration and the historic influences resulting in differentiation and specialization among them, observing the dynamics of farmers' interactions with their natural environment, socio-economic settings and the public policy, and highlighting in details the strategies pursued by farmers to deal with their continuously changing conditions.

Nevertheless, Wattenbach (2006) relies principally on qualitative analysis, fails to indicate precisely the relative magnitudes of problems faced by the farmers. The approach, though was successful in identifying the main constraints confronting rural development in the Country and their relative significance in different farming zones and for different household typologies, is unable to quantify these constraints, and therefore, could not prescribe specific and detailed solutions to deal with the materialistic problems. In the region targeted by this thesis, Wattenbach (2006) defines the liquidity constraints and the lack of access to crop finance as a serious constraint to many farming households. He then recommends offering a functioning credit market in order to revive the rural economy and to increase the profitability of production for the producers who pay very high capital costs to finance their farming operations. However, due to the lack of detailed quantitative analysis, it fails to specify the activities that such credit market should target, as it fails to identify the ways in which farmers may respond to changes in any of the key policy parameters, which may motivate farmers to adjust significantly their resources allocation.

Chapter 2. Farmers' Environment

Many factors contribute to the way the agricultural sector is shaped in Syria today. Despite problems and various difficulties that have characterized Syrian farming in the past decades, agriculture is still one of the predominant sectors in the economy and one which the Country has to count on in the future for its social and economic development. At the level of the zone of interest in this study, agriculture is considered to be the dominant economic activity, and the bulk of its population is either directly involved in agriculture or involved in other economic activities very much linked to the agricultural sector such as the commerce of agricultural outputs and the provision of agricultural inputs.

This chapter aims to describe the overall framework under which the targeted farmers operate and make their production decisions. Therefore, after a general description of the study area, the conditioning factors that shape agricultural sector in the study area will be presented. These conditioning factors can be classified under two other categories: the **social and economic conditions** of rural areas, and the wide spectrum of **public policies** affecting the sector.

2.1. General description of the study zone

The study covers the large zone of the North-East of Syria, which is composed of three governorates: Deir-Ezzour (DEG), Al-Rakka (RAG), and Al-Hassakeh (HAG). The overall zone will be later referred to in this report as DERAHA. Each of these governorates consists of three or four administrative mantikas, with the mantikas of Al-Hassakeh Centre, Kameshli, Al-Malkiya, and Ras-Elein falling in HAG, Al-Rakka Center, Al-Thawra, and Tal-Abiad falling in RAG, and Deir-Ezzour Centre, Al-Mayadeen, and Bokmal falling in DEG.

The Mediterranean climate prevails in DERAHA, which is characterized by rainy winters and dry-hot summer, with short autumns and springs. Climatically, DERAHA extends over the five agro-climatic zones of the Country (see **box 1**) although the area of the Agro-Climatic Zone I is relatively small. Humidity rate is high in winter (60-75%) and very low in the summer (20-50%). The daily temperature gap between day and night (the highest 47.7 at day and the lowest is -3.4) might reach 23 degrees (SOFA 2002).

The two largest rivers of Syria run through the area of DERAHA which are Euphrates and Al-Khabour. Euphrates sources in Turkey and enters into Syria where it runs for 680 km, and it has an average flow of 1037 CM per second. Al-Khabour sources from the north-east of DERAHA in HAG and it runs for 552 km with an average flow of 22.5 CM per second. DERAHA is also endowed with a third river, Al-Balikh, which extends for 100 km with an average flow of 25 CM per second.

DERAHA also includes the largest dam in the Country (Euphrates Dam) that has a storage capacity of 14.1 billion CM, it includes as well several other dams from which the most important are Al-Khatounieh Dam (in HAG) and Al-Ba'ath Dam (in RAG). Moreover, many dams were built on the other rivers; for example, ten small dams were built on the Al-Khabour river with a total storage capacity of 409 million CM.

With reference to **Table 2.1**, the population of DERAHA accounts to about three million inhabitants forming only about 17% of the national population. The **Table** also reflects the relative importance of rural population in the area showing that the region has a higher share of rural population with respect to the national figure. This indirectly reflects the high reliance of the area population on agriculture as the major income source as it was highlighted by other sources (Wattenbach 2006).

Box 1

The concept of agro-climatic zones

Due to the diversity and the importance that agro-climatic conditions have on agriculture and other human activities, from a planning point of view Syria has been traditionally divided up in five major **agro - climatic zones** often referred to as **settlement zones.** These agro-climatic zones are the Syrian approach to defining land use suitability classes, with implications for the legal position of crop farming, support services and delineation of intervention areas of Government supported projects. The definition of the five zones given below is adopted from the Ministry of Agriculture and Agrarian Reform (MAAR) annual statistics. The mapping of the zones and hence delineation of land in the different classes is subject to revisions by Government committees.

Syria is divided into five agro- climatic zones according to annual precipitation and rainfall probability:

Zone 1: With annual rainfall over 350 mm, its area is 2,701,000 ha and forms 14.6% of the Country's area.

The zone is divided into two areas:

a) This with annual rainfall over 600 mm where winter rainfed crops can be successfully planted.

b) This with annual rainfall between 350- 600 mm and not less than 300 mm during two thirds of the relevant years i.e. it is possible to get two seasons every three years and the main crops are wheat, legumes and summer crops.

Zone 2: It has an annual rainfall between 250 - 350 mm and not less than 300 mm during two thirds of the relevant years i.e. it is possible to get two barley seasons every three years and in addition could be planted with wheat, pulses and summer crops. The common rotation in this zone is:

- On deep soil: wheat-pulses and forage legumes – a summer crop is planted if winter rain is sufficient, otherwise fallow will take the place of summer crop.

- On shallow soil: mainly barley, but part of the land is planted to cumin. Fallow is rare.

The area of this zone is 2,470,000 ha and it forms 13.3% of the Country's area.

Zone 3: It has an annual rainfall of 250 mm with not less than this amount during half of the relevant years i.e. it is possible to get one to two seasons every three years and the main crop is barley, although legumes could be planted. Fallow is practiced in case of capital shortage. The area of this zone is 1,306,000 ha and it forms 7.1% of the Country's area.

Zone 4: It has an annual rainfall of between 200- 250 mm with not less than 200 mm during half of the relevant years i.e. it is good just for barley, which in some years is grazed since the plants do not grow enough to be harvested. Fallow is practiced in case of capital shortage. The area of this zone is 1,833,000 ha and forms 9.9% of the Country's area.

Zone 5: (Desert and steppe) this area covers the rest of the Country's land. It is not suitable for rainfed planting. The area of this zone is 10,208,000 ha which forms 55.1% of the Country's area. It is natural grazing for sheep and camels.

Source: adapted from MAAR Statistical Abstracts.

About 25% of the total cultivated area of DERAHA is irrigated while the rest is cultivated without irrigation, relying only on rainfall that fluctuates according to time and space. Irrigation is usually tuned according to the availability of irrigation water, but in many cases according to the type of crops being grown. In the areas where irrigation water is available, farmers tend to use water for all crops even for winter crops such as wheat and barley unless rainfalls are sufficient and in time, which happens only in some years in the Agro-Climatic Zone I. The scarcity of rainfall and its misdistribution in most agro-climatic zones makes it unreliable for agriculture even in most winter seasons. Summer crops such as cotton, maize and sugar beet are always grown as irrigated crops.

There are three irrigation sources in DERAHA: private wells, public networks and rivers. Major irrigation source in DERAHA is the private wells which irrigate about 62% of the total irrigated area. However, the importance of private wells for irrigation differs across the three governorates of DERAHA. While it is the dominant source in HAG where it irrigates about 85% of the total irrigated area, it only irrigates some 26% in DEG where the dominant source is the Euphrates rivers (58%). In RAG instead, public networks are the most important and they irrigate about 40% of the irrigated area (**Table 2.3**). Public networks generally in Syria are the results of the large Government investments and the beneficiaries of these networks are subject to annual fee (refer to **section 2.2.1**).

Although modern irrigation techniques are present in the area but their importance is negligible. The area irrigated by them did not exceed 2% in 2004 (MAAR 2005). Hence, the dominant irrigation mode is the traditional flood irrigation which is considered highly inefficient.

Table 2. 1. The importance of DERAHA in the national context

Element	Syria	DERAHA	Share (%)
Total population (thousand inhabitant)	17,921	3,073	17
Rural population[1] (thousand inhabitant)	8,333	1,863	22
Total area (thousand ha)	18,518	7,601	41
Cultivated area (thousand ha)	5,682	2,576	45
Irrigated area (thousand ha)	1,396	764	55
Rainfed area (thousand ha)	4,286	1,812	42
Wheat area (thousand ha)	1,668	923	55
Wheat production (thousand ton)	4,041	1,472	58
Cotton area (thousand ha)	193	142	73
Cotton production (thousand ton)	711	537	76
Sugar beet area (thousand ha)	28.2	8.6	31
Sugar beet production (thousand tom)	1,366	320	23
Barley area (thousand ha)	1,363	747	55
Barley production (thousand ton)	784	302	39
Yellow maize area (thousand ha)	50	319	63
Yellow maize production (thousand ton)	177	117	66

Source: elaborated from NAPC database, 2007 (www.napcsyr.org), and the CBS (2006)

The other most important income sources in DERAHA are the public sector employment and agricultural casual labour. The importance of such activities for income generation is different for different farm households. Their importance decreases as the well-being status of the farming family increases, and they become irrelevant for many farming households who have relatively quite large farms. On the other hand, Government employment is not available for all people, but it is noticeable that the education level of well-off farmers is higher so they are more likely to get stable jobs outside the agricultural sector. Casual agricultural employment is only available at specific times of the year which causes the income of the households depending on it to be highly unstable. It reaches its peak during the cotton harvesting season in which many casual agricultural labourers come from other parts of the Country seeking employment in DERAHA as the domestic labour does not usually suffice the demand for it.

Table 2. 2. Land use in DERAHA (2007)

Governorate	Total area (thousand ha)	Cultivated and Irrigated	Cultivated (rainfed and fallow)	Un-cultivated, (forests and steppes)	Building & Public Utilities	Swamps, lakes, rocky and sandy lands
HAG	2,333	18%	49%	27%	4%	3%
RAG	1,962	10%	31%	50%	3%	5%
DEG	3,306	5%	2%	58%	1%	36%

Source: elaborated from NAPC database (www.napcsyr.org)

The DERAHA is a specialised region in the production of the so-called strategic crops especially wheat and cotton which are the main sources of farm incomes nowadays. The area produces some 58% and 76% of their national outputs respectively although the cultivated area of DERAHA does

[1] Population is considered rural in Syrian statistics when the population centre has less than 20 thousand inhabitants.

not exceed 45% of the national figure, reflecting a kind of concentration of the productions of these two crops in the region. Other important crops are yellow maize, barley and sugar beet presenting some 66%, 39% and 23% from their corresponding national figures respectively.

Table 2. 3. Irrigated land use by irrigation source and technique in DERAHA (2005)

governorate	Total irrigated area (000 ha)	Irrigation water source			Irrigation techniques		
		% irrigated from wells	% irrigated from public networks	% irrigated from rivers	%irrigated b y flood	% irrigated by sprinkler	% irrigated by drip
HAG	476	37.95	40.12	21.93	97.53	2.13	0.34
RAG	196	26.72	15.12	58.16	99.29	0.21	0.50
DER	145	83.84	8.81	7.35	97.09	2.63	0.28
total	817	62.71	17.44	19.85	97.58	2.08	0.34

Source: MAAR (2005)

Livestock production has some importance in DERAHA especially for the poor who rely on it as a secondary source of income or for home consumption. However, livestock production is almost always an activity not integrated with the cropping activities since farmers use commercial concentrates to feed their livestock in case they have cows. In case they have sheep, they usually send them too to graze in the neighbouring pastures or they join larger flocks that go to graze in the Syrian Steppe (Wattenbach 2006).

2.2. Government policies and interventions

While a detailed description of the overall government agricultural policy is available in other sources (Westlake 2001, Wattenbach 2006 & SOFA 2007), this chapter is devoted only to describe and discuss mainly the policy instruments that affect the decisions making processes of Syrian farmers, which need to be modelled.

2.2.1. Irrigation-related policy

Speaking about irrigation policy means in general policies related to the provision of irrigation water at the farm level. However, the purpose of this section extends beyond that. It also aims at describing other kinds of policies that affect all kinds of water accessibility by farmers and determine the costs' type of water incurred (whether fixed or variable) as well as the magnitude of these costs. In this respect, one can categorise irrigation water sources available to farmers DERAHA into three types: public nets, rivers and springs, and private wells as explained in the previous section.

The Government has constructed over the last three decades a large number of irrigation canals that drain water from dams and make it available at the farm level. Most maintenance costs of these projects are borne by the Government. Farmers who have access to public nets usually pay an irrigation fee per hectare of land on an annual basis, which are expected to contribute only slightly to the maintenance costs, since the fees are very low. Such fees are paid annually regardless of the amount of water used.

Farmers using rivers and springs for irrigation do not usually pay fees. They either draw water directly from the source using a private engine, or they organise themselves in consortiums and purchase one large engine that serves all members. The choice usually depends on their location (far from or close to the water source) and on their financial capacity. The cooperation mode is very common formally in DEG. In such a case, pumping costs are borne by all members each according to his total land area.

Pumping costs become very significant when farmers use private wells as the main source of irrigation. Such costs increase as the depth of wells increase, but they also depend on the capacity and age of the pump-set used. Most pump-sets in DERAHA work on diesel, while the rest uses electricity but the percentage of the latter is negligible. The price of diesel in Syria has been controlled by the Government for a long period of time, and it used to be until recently very subsidised (refer to **section 4.1.1**).

2.2.2. Licensing policy

Despite the fact that planning has recently become indicative in Syria, the annual agricultural plan of the Ministry of Agriculture and Agrarian Reform (MAAR) is still a central element of the agricultural policy in the Country. It aims at directing farmers towards a particular pattern of land use perceived by policy makers as best able to achieve the national objectives. The plan, besides, serves as a framework at the beginning of each cropping year to guide the provision of credit, inputs and other services to farmers directly through the ACB or indirectly through the agricultural cooperatives. In addition, it is used as a guide to plan the subsidy services. While a detailed description of the planning and licensing systems is available in other sources (Westlake 2001 & Wattenbach 2006), the relevant part to this study is the one related to the licensing systems of certain crops that are grown in DERAHA. For sugar beet and cotton, farmers are not allowed cultivating these crops in excess to the areas permitted in the licensing systems if they are to get the official supported price for their produce.

These licensing systems are set according to a specific mechanism based on the shares of strategic crops set in the central plan. These shares are determined in light of the estimated needs of the national economy as well as the estimated availability of irrigation water. Then committees from the directorates of agriculture of each governorate discuss the previous production plan and identify the new irrigated areas in coordination with the extension units of the relevant villages. Then the directorates of agriculture propose a new production plan and send the figures of the irrigated areas with the expected production and yield to the MAAR to be discussed in the Presidency of the Ministers Council which gives the final approval to the plan. Then the MAAR sends the plan to the directorates of agriculture in the different governorates, which distribute it to the agricultural extension units and the farmers' cooperatives to be finally performed.

Each farmer has a fixed percentage to plant any of these two crops (cotton and sugar beet) according to the land area and the irrigation water resources to which he has access. Any farmer that has at least one hectare can get a license, provided the existence of a formal document stating that he has access to the land. However, if irrigation water source is a well (underground water), a farmer should also provide a document stating the well is licensed, otherwise, a special committee from the MAAR has to ensure that the well is appropriate, so the farmer may obtain the license even if the well is unlicensed (NAPC 2005b).

2.2.3. Pricing and delivery policy

From a policy viewpoint, crops in Syria can be classified into strategic crops and other crops. Strategic crops are those whose prices are affected directly by Government pricing policy, either through administering fixed prices or through setting floor prices. Crops considered strategic in Syria are seven: wheat, barley, cotton, sugar beet, tobacco, lentil, and chickpea. All of these crops are grown in DERAHA but tobacco whose total production takes place in the western part of the Country. The Government annually sets prices for all strategic crops at which public agencies and establishments will buy the crops' outputs. These prices are applicable at the same level throughout the entire Country. In addition, they are all determined based on unit costs of production, aiming to ensure that farmers can cover the production costs and make some profits. Such a way of price setting explicitly has the aim of isolating farmers from market forces and motivating farmers to produce specific crops in line with policy preferences.

For cotton and sugar beet, the officially administered prices are the only ones at which farmers can sell, as the state-owned establishments are the sole buyers of these crops. However, this is not the case for wheat, barley, lentil and chickpea, since farmers can also sell to private buyers. Under such a case, the official price is in effect a floor price, and farmers do occasionally sell to traders at less than the official price because the trader is able to offer a purchase package that the farmer finds more attractive than the alternative offered by the Government, due for example, to more attractive payment terms. In addition, the official prices of lentil and chickpea have been, for several years, much lower than those prevailing in the market, implying that farmers do not usually sell them to governmental agencies, where the latter plays the role of the last resort.

Based on the above, strategic crops can be also distinct in two categories according to differences in the delivery policy. Cotton and sugar beet are those whose output must be totally submitted by farmers to the relevant State establishments since they are processed by state-owned factories. However, for wheat, barley, lentil and chickpea, farmers are not obliged to sell to the state establishments. In fact, this categorization is in line with price policy, in the sense that crops that must be submitted totally to the relevant government establishments are those which have fixed prices, while the rest are those who have floor prices.

The General Establishment for Cereal Processing and Trade (GECPT) operates 140 collection canters for the purchase of wheat from farmers. As Barley is used principally for animal feed, producers can retain it for their own livestock, sell it to neighbouring farmers, traders and private feed millers, or sell it to the General Establishment for Feed (GEF), which continues to act as a buyer of last resort. The relative throughput of the public and private sectors varies markedly from year-to-year, with the GEF buying substantial part of the crop when its buying price is above export parity, but buying very little when world prices are strong and private traders bid up the domestic buying price. For lentils and chickpeas, the GECPT and the General Company for Mill (GCM) own a total of seven lentil processing and splitting plants. Many private factories process lentils and chickpeas for a fee, whose market is highly competitive.

Cotton, instead, must be delivered to the Cotton Marketing Organization (CMO), which has 16 saw ginneries. The CMO purchases from farmers immediately after harvest and then processes its resulting stock of seed cotton over a period of some ten months. Farmers must also sell their entire sugar beet crop to the General Establishment for Sugar Industry (GESI), which has seven sugar factories, six of which process beet.

The prices of other crops (non-strategic) are determined through the interactions of market forces without any direct intervention from the Government, and farmers sell the output of these crops in the free markets (refer to **section 2.3.4**).

2.2.4. Input distribution policy

The ACB is still the major distributor of physical inputs in the Country although the private sector has been actively involved in that recently. Most Syrian farmers still get the major part of their inputs requirements directly from the ACB or indirectly through the agricultural cooperatives. The ACB sells to farmers mainly fertilisers, seeds of major crops as wells as some inputs related to specific crops at prices fixed by the Government that are usually lower than their market counterparts. The ownership of an agricultural license is essential to buy inputs from the ACB, in which inputs are sold according specific figures that reflect crops requirements of each input per hectare (Parthasarathy, 2000).

Prices of fertilisers had been fixed from the early nineties until two years ago when the Government raised them slightly although they remained heavily subsidized. In 2009, the Government raised their prices significantly to make them very close their international market counterparts.

The ACB is also the only responsible of distributing to farmers the seeds of the some strategic crops, namely these of wheat, cotton, and sugar beet. The principle of this activity is very similar to that of fertilizers; however, the source of strategic crops' seeds is mainly domestic where the General Establishment for Seeds Multiplication (GESM) plays the central role on providing the ACB with the required seeds. The Government objective from controlling the distribution of seeds is to motivate farmers to grow the high-yielding varieties developed by the GESM in the ecologically suitable areas where they can express their yield potentials in the best way.

The ACB, in addition, provides farmers with other minor inputs that are related to particular crops. Examples are the jute bags to which farmers use to collect cotton when they prepare it for delivery to the CMO, and hemp bags used to collect wheat. In addition, the ACB distributes some types of plant protection chemicals, although the major part of these items are sold by the private sector, mainly through the so-called "agricultural pharmacies", which are specialized stores run by agronomists, who besides selling chemicals, improved seeds, medicines for livestock, etc, give farmers advice on technical issues. Prices of such items are not controlled by the Government and they are determined by the market forces.

2.2.5. Credit policy

The ACB is perhaps the most important institutional instrument of the Government to promote agricultural production and productivity and raising the standard of living of the rural population. It is, above all, the main credit provider to farmers, in which it offers Syrian farmers cash and in-kind loans to fund farming and animal husbandry activities. The ACB is in a position to provide farmers with the following services: loans, current account facility to be drawn according to need, discounting of bills of purchase presented by the borrower, and extending guarantees for payment on the due date versus supplier credit. Loans offered by the ACB can be classified into three categories (short-term, medium term, and long term), each of them cover specific types of activities and investments with different interest rates and different duration for repayment (Parthasarathy 2001).

Short –term loans aim to cover farm expenses such as ploughing, harvesting, irrigation and fuel, fertilisers, seeds, small tools and animal feeds and veterinary medicines. In addition, they cover the costs of maintaining agricultural machinery and pumping-sets as well as the costs of agricultural products' storage. Such loans have to be repaid in a period of one year maximum, and it is offered in cash and in kind (usually in form of fertilizers and seeds). Loans provided to fund the farms expenses are subject to the seasonality of agricultural activities in which it is not possible to obtain any credit before the dates specified in "requirements' tables" special for this purpose. These tables include also the inputs required by one hectare for each cropping activity, and the dates of loan repayments.

Medium and long term loans relate to investments at the farm level. The medium-term loans are given for periods more than one year but not exceeding five years. They cover purchasing machinery and tools required for agricultural production, land reclamation and other activities that require similar costs. The long-term loans are given for periods of more than five years but not exceeding ten years and they are aimed at financing the construction of stores, land improvement, forestry projects, fruit tree planting programs and cold storage facilities, in addition to modern irrigation schemes and the processing of both plant and animal products.

Each farm household must have a crop license as a prerequisite to obtain credit and/or to purchase inputs from the ACB. The crop license is issued every year and contains details of farm size, agro-ecological zone, whether the crops are irrigated or rainfed, which are the crops "allowed" to be grown in the following agricultural year, and the recommended requirements of fertilizers, seeds and chemicals. However, for farmers who are members of cooperatives, the latter perform all the procedures needed to access credit on behalf of their members.

For medium and long-term loans, the access procedure is more protracted. Many farmers complain about the dissatisfaction over long procedural delays in processing applications for such loans. Many others have the impression that the bank does not give long-term loans, which poses the importance of diffusing information within the farming community so farmers can make full use of available credit opportunities. Property collateral is essential for eligibility to medium and long-term loans. Authorized appraises along with the other documents connected to the short-term loans must be submitted. It is also necessary to submit documents of technical design about the project prepared by specialist technicians and approved by the relevant public institutions, in addition to submitting a report of economic feasibility studies. Some other conditions exist for some specific projects. However, the loan is taken up for consideration only after receiving the report of the inspection committee (special for this purpose). Farmers find it difficult to obtain loans for machinery like harvesters and tractors. They have the impression that lower priority is given by the ACB to medium and long term loans. This precludes important activities like land reclamation and fruit tree replanting (Parthasarathy 2001).

In addition to what is mentioned above, the ACB plays an intermediating role between several public projects and commissions from one side and farmers and rural people from the other side.

Such projects usually aim at supporting rural and agricultural development through the provision of loans and banking services to their beneficiaries such as the loans of Unemployment Combating Commission. Another example is the National Project for Conversion to Modern Irrigation (NPCMI) which belongs to the MAAR and aims to convert all irrigated areas in the Country to modern irrigation.

2.3. Socio-economic environment of the farming community

This section is devoted to describe the socio-economic environment surrounding farmers in DERAHA, and to discuss in some details the social factors that are likely to have an impact on farmers' decisions and choices. We start by discussing the land tenure systems that exist in the region, then labour, credit and product markets are discussed individually, the section is ended by some comments about interlocked markets that exist in the region and their relevance to the argument of the thesis.

2.3.1. Land tenure system

The importance of land markets varies considerably among different areas of the Country, and sometimes within on area. The long-term effects of land reform are a critical issue in some parts of Syria since the population growth led over time to increased pressure on agricultural land resulting in considerable land fragmentation. The sale of agrarian reform land was until recently illegal, but became recently legal under certain conditions.

In some cases, the law of agrarian relations has led to the effective transfer of land to former sharecroppers, which obtained continuous usufruct rights, after sharecropping it for many sequential years. However, they are nevertheless obliged to pay a proportion from the total output to the original owner. This proportion differs according to the sharecropping arrangements agreed upon between the two parties, in which the share of the owner does not exceed 20% in case she only provides the land. This is very common in DEG and it also exists to some extent in RAG, but it has no relevance in HAG. In the latter, however, seasonal sharecropping is relatively common in the larger farms, whereby sharecropping is linked to a specific crop (cotton or wheat) and sharecroppers take care of all operations while owners visit the farm for important operations (Hamza 2004).

The lack of updated title deeds generally presents for many farmers a constraint to access credit through the formal channels and hence reduces investment. Slow administrative procedures related to the land registration affects tenure arrangements. Lawful and practical restrictions on changing ownership of agrarian reform land aggravate the situation. An increasing number of holders operate on land with title deeds issued in the name of deceased parents. The resulting restricted credit access will affect production and farm income. The regulations governing the transfer of registered land and issuing updated title deeds require for that reason urgent attention. The development of parallel arrangements is otherwise the only viable solution for farmers, but these will tend to favour the stronger negotiation partner at the detriment of the weaker one, i.e. the poor (Wattenbach 2006).

2.3.2. Labour market

Syrian population is currently estimated at slightly less than 20 million, with a labour force of 5.5 million, 19,2% of which is employed in agriculture. If we add the agricultural based industry and service, the relevance of agriculture for employment becomes evident.

Most of the farms are operated by the owners and their families. The intensity of farm labour depends on the crop and the relative degree of mechanization of farm operations. Cereal production is almost fully mechanized (with exception in small areas of wheat cultivation for home consumption on steep slopes). Cereal cultivation is therefore irrelevant for the rural employment. In contrast, beets and oilseeds provide small employment opportunities on larger farms, while most small farmers will not engage higher labour for these crops (Wattenbach 2006).

In DERAHA, industrial crops are the largest providers of agricultural casual employment, and among them the large cotton producing areas attract during the picking season large flows of casual labour across the Country. Given the labour intensity of picking, which is mostly carried out by female labourers, even medium and small sized farms often employ additional labour to complement available family labour especially at the harvest seasons (Hamza 2004).

The survey findings of this study found out that in several areas of DERAHA, many poor families (landless in particular) engage in sharecropping arrangements with "landowners". This applies in particular the two main crops in the area, namely cotton and wheat. Given the lack of cash from the side of the sharecropper, the contractual arrangements tend to be very simple with all inputs being provided by the investor, while the sharecropper guarantees high quality supervision of the crops, as he lives in a tent next to the field for one season. The quality of irrigation and prevention of theft are important additional duties. Sharecropping arrangements are more prevalent in the irrigated parts, since labour requirements per hectare are higher for irrigated crops and the relative saving on supervision cost is larger compared to rainfed crops (Wattenbach 2006).

Mobilization and organization of labour force

The source of labour engaged in agricultural production differs from one region to the other in the Country. This applies very much to DERAHA. In DEG, agriculture depends mainly on family labour, and when hired casual labour is needed, it is very likely that they come from the same or the neighbouring villages. Labour from other regions of the Country may come only during the harvesting seasons of cotton and sugar beet. The same observation can be said about the RAG although it may be safe to say that the latter absorbs more migrant labour during the harvesting seasons of cotton and sugar beet, which is very true in the mantika of Tal Abiad where farms are relatively large and productive and the area has a relatively low population density (Wattenbach 2006).

Poor farmers and landless rural people are the basic providers of the casual agricultural labour, whose organization and mobilization function in accordance with the local demand in one area or another. Traditional contractors, the *chaweshes*, perform these functions. They organize labour system whereby labour demand and supply meet. They pool labour from areas of excess supply and make it available in different areas according to the market demand, which increases significantly in autumn, when the harvest seasons of several major crops in the Country (Forni 2001).

Each *Chawesh* organizes 25 to 30 workers, mainly women. He assumes all risks connected to labour identification and employment. Therefore, he organizes travel and residence when away from home usually in tent (Forni 2001). He is also responsible for paying the workers who have no direct dealings with the employing farmers. This makes the effective wage that the labourers receive less than the real wage paid by farmers, since the *Chawesh* takes a commission of 20% from each employee in addition to a daily wage paid to him directly from farmers as a remuneration for supervising work. The commission he receives from employees should be in theory equivalent to the cost of housing and transportation he guarantees for them (Wattenbach 2006).

The role of women

Agrarian relations from a gender perspective indicate that, on the field, women usually take the responsibility of weeding and harvesting and men do other activities such as irrigation, tillage, etc. Increasing feminisation of agriculture has recently become a general phenomenon because men usually enter non-agricultural activities. This may from the one side increase the burden on women, but on the other side, it increases their participation in decision-making inside household (Forni 2001).

2.3.3. Credit market

Liquidity is among the primary constraints of poor and medium household and influences the production decisions in most farming systems. Constrained access to crop finance has a serious impact on their possibilities to improve agricultural incomes. Frequent failure to repay earlier credit leaves many poor household excluded from formal credit trough the ACB. At present, their possibilities to invest in agricultural production depend on informal credit access. These informal credits are expensive and the high figures suggest cases of abuse by traders and input providers. However, such credit necessarily contains a risk premium, as the enforcement possibilities of the credit given outside the formal legal framework are low and risks for the creditor are high as not guaranteed though a collateral (Wattenbach 2006).

Many farmers borrow from friends or relatives living outside the Country, mostly other Arab countries (Lebanon and Gulf States). Furthermore, machinery suppliers are a common source of finance for purchase of equipment. The procedures are short and simple; although interest rates are high (they vary from about 20% up to 40%). Interest on such deals is generally made a part of the price. Farmers are aware of the higher cost incurred by this route of financing but do not mind such additional cost for the sake of saving time and avoiding inconvenience (Wattenbach 2006).

For production expenses, the alternative sources of credit are the input suppliers, output dealers, exporters and cold storage units' owners. Input suppliers are generally small traders and do not have the capacity to extend credit covering the whole crop duration. They usually provide fertilizers, seeds, and plant protection chemicals. Farmers are generally anxious to apply chemicals to protect the crop and the expenses they have already incurred on the land and for this reason consider agro-chemicals to be of higher priority over other inputs. Consequently, they are well motivated to keep good relations with agro-chemical dealers by repaying loans relatively more punctually (Wattenbach 2006).

The main sources of informal credit for cotton and wheat producers are the "informal" traders of wheat and cotton. Farmers who depend on such credit are exclusively those who have accumulated debt with the ACB and lost access to its credit. This usually occurs after farmers have suffered from a significant production loss caused by drought or epidemic, or in cases of affording additional expenses to deal with personal problems. Therefore, these farmers are usually from the poorest. In such cases, a trader buys the production of wheat or/and cotton (which are state-controlled crops) in advance at prices much lower than the official prices (about 30% lower). The trader gives cash to the farmer when needed according to agreed arrangements (usually half of the amount at the beginning of the winter season and the rest as instalments). After the production is delivered to the trader, the latter manages to sell it to the relevant governmental institution. Sometimes, the production is sold through the cooperative of the village for the trader using the name of other farmers. Such activity is usually protected by the social norms and traditions although it is illegal.

Given the above, it seems that the current credit system favours to some extent the so-called strategic crops particularly wheat, cotton, and sugar-beet. Farmers who cultivate these crops have relatively easier access to credit provided in kind by the ACB in form of seeds and fertilizers. This encourages farmers facing a liquidity problem to cultivate these crops. The possibility to access these informal sources of credit depends also on cultivating the crops that have stable prices and are easy to trade, which are, once again, wheat and cotton.

2.3.4. Product markets

Farmers face serious problems in marketing crops for which the Government intervention is minimal. Crops such as fruits and vegetables as well as a large group of legume, cereals (other than wheat and barley), oilseed, and other crops are marketed through the private sector channels and their prices are determined through the interactions of market forces. The absence of stabilization policies leaves the determination of prices to be very much affected by seasonality of outputs, resulting in fluctuating prices that expose farmers to a high level of price risk.

Farmers' attitudes towards risk influence the way they prefer to market their output. Aiming to cope with risk, many farmers prefer to sell their crops on the field at the fixed price pre-agreed upon with the buyer, who is a kind of traditional guarantor, called *damman* in Arabic. In this way, farmers express their willingness to sacrifice, on average some margin for securing a minimum level of revenues and, and at the same time to avoid the complications associated with transporting the outputs to the main wholesale markets. Not surprisingly, this practice is very common for crops that suffer the most from price fluctuations as they are perishable and do not have long-term storage facilities, such as onion, and garlic (Wattenbach 2006).

Some crops that are easy to store in the open field, such as cumin, anis, and black seeds are marketed on the field. Farmers harvest the produce and then sell it to traders specialized in such activities and usually involved in export activities or at least linked to some exporters. The nature of such crops assist farmers in coping with the price risk; however, they usually sell their output under unfavourable conditions due to their lack of liquidity needed for other production activities or for consumption purposes (Sadiddin 2004).

Most fruits and vegetables are marketed in wholesale markets existing in each governorate main centre. In Damascus's wholesale market, there are around 400 traders, half of which act as commissioners and the other half as wholesalers. The absolute bulk of the trade is for wholesale, although there is some retail. The market lacks a system to monitor the access of products on the market.

Officially, the commission to be paid for the sale of the output on behalf of farmers is 5% (maximum fixed by the former Ministry of Economy and Trade), although real commissions are reported to be between 20% and 30%. Sometimes, commissioners anticipate loans to farmers, in cash or in kind (fertilizers, seeds, etc). This fact, and the personal connections and trust, have the consequence that normally one farmer is linked to a specific commissioner, or eventually to a few commissioners, one in each destination markets. The commissioner can sell to small wholesalers or to retailers either in cash or on credit, with payment occurring usually from one week up to one month later, depending on the market condition (sale on credit is more common when there is a product surplus). Wholesalers and commissioners are not specialized by product, due to the seasonal pattern and the need to operate continuously. However they are often, more or less, specialized by region, which determines also a partial product specialization (Sadiddin 2004).

Between the agricultural producers and the final consumers there is often a long chain of intermediate operators. In a not well integrated agricultural sector, these operators represent the only way to ensure an adjustment between demand and supply. The government, which in other cases exerts a very strict control over the economy, is in this case almost absent.

2.3.5. Interlocked markets

Interlocked markets occur as one possible response to market failures, whether these failures characterise produce or factor markets. In Syria, there are many examples of interlocked markets. Sharecropping is clear example of interlocking the markets of land, labour and credit. Such practices are very common in DERAHA where state-manipulated (strategic) crops are grown in large quantities. The sharecropping arrangements differ slightly according to the crops' characteristics and their requirements in terms of labour and credit, but the principles are very similar. The landowner provides usually the major part of the credit in addition to the land, while the tenant (sharecropper) provides the labour, and they share the output at the end. These practices are only common for the so-called strategic crops because they are the only ones that have stable prices and therefore can guarantee relatively stable incomes for both parties.

Another interesting example of interlocked markets can be categorised under *forward contracting*. The arrangements differ according the type of the produce and the extent to which the industry with which the produce is integrated is developed. If the industry is enough developed as the situation of orange and tomato commodity chains, a contract is written, at the planting time or maybe later during the season, between the farmer and the purchaser who might be a manufacturer or a trader. They both agree in the contract on the delivery price and quantity, which might be subject to some amendments in some conditions. Agreeing on quality may be also important element of the contract, especially for fresh produce for exports. Such arrangements are important for farmers to achieve two different objectives: reducing price risk (however, the agreed price is probably lower than the market expected price) and easing liquidity constraints since farmers can ask to have some payments before the delivery of the output.

Moreover, there exists another type of interlocked markets that have been developed primarily due to governmental failure in implementing price and the delivery policy of some strategic crops, namely wheat and cotton. The traditional name of this phenomenon is *salaf*, which means "selling in advance". This phenomenon is much diffused among farmers who accumulated debt with the

ACB and lost the right to its credit. Therefore, they are usually from the poorest. Consequently, they started depending on some traders to have credit at very high interest rate reaching 40%. In such cases, a trader buys the production of wheat or/and cotton (which are state-controlled crops) in advance at prices much lower than the official prices. The trader gives the money to the farmer when needed according to agreed arrangements between them (usually half of the money at the beginning of the winter season and the rest as instalments). After the production is delivered to the trader, he manages to sell it to the relevant governmental institution as explained in **section 2.3.3**.

Despite of some similarities between *forward contracting* and *selling in advance*, they are deeply different. These differences lie in the core function that each of them plays in serving the objective of both parties. In forward contracting, the main objective of both parties is risk reduction. Farmers would like to reduce price risk while the purchaser wants to reduce risks associated with price, timing of delivery, and quality. Obviously, such arrangements exist for produces whose prices are determined by the interaction of market forces and are not directly affected by the government price policy, and therefore, they are very exposed to price uncertainty. Credit in this context is an additional component, which is usually offered to the farmers to help him comply with the terms of the contract, or to attract him to renew the contract for further seasons, so it is mainly an incentive measure used by the purchaser to keep her suppliers of raw materials. This is true although there exists features of advantageous behaviour from the purchaser side due to asymmetric information about prices and market conditions, on which the government role must be essentially focused on easing the diffusion of information.

However, in the case of *selling in advance*, the fundamental problem that confronts farmers is the lack of cash capital. As explained above, the problem starts when farmers experience a significant output loss caused by drought or epidemic, or in cases of having to afford additional expenses for personal problems. This causes them to fail to repay the debt to the ACB resulting in their exclusion from access to further credit. Farmers then become ready to accept very exploitive terms in order to obtain the needed cash whether to cover variable costs of production or survival expenses. Risk management or reduction has nothing to do with these practices since the latter are linked to crops that have fixed or floor prices and consequently are far from being price risky. Farmers accept them only to ease the liquidity constraints, while traders make huge profits without taking any risk, by appropriating the major part of farmers' surpluses.

Chapter 3. The analytical model

This chapter aims at describing the mathematical programming model used in the analysis. We start by discussing the basic assumptions of the model, followed by a mathematical description of the model equations. Then the model setting-up and data description will be presented. The chapter will end with a section on solving and validating the model.

3.1. Basic assumptions

The model consists of a set of quadratic programming models, one for each farming typology. The representative farming models are solved with common vectors of prices to represent the common economic features of the region in question (DERAHA). However, matrices of technical coefficients are in many cases differentiated to reflect agro-climatic differentiations in DERAHA. At the end, each single model has its own parameters and constraints that define the structure of each representative farm.

Many assumptions are maintained for each representative farming model. Each farming system is presumed to maximise the expected utility of its agricultural income given a set of constraints imposed by the availability of land, water, family labour and capital. Other constrains are also imposed by technical conditions (agrarian rotation) or policy intervention (licensing systems of strategic crops). To put the expected utility theory in practice, we adopt the mean-variance approach, which assumes that the expected utility of farming income can be measured by the certainty equivalent which is, in turn, equal to the expected farming income minus a term that measures income variation as shown in equation 1.1 (**section 1.3.3**).

Risks faced by Syrian farmers can be classified under two types: risks associated with markets and those associated with weather and climate. While the latter causes fluctuations in output, the former cause fluctuations in prices, both of which may cause large fluctuations in the farms' net revenue. Nevertheless, only price risk is considered in this thesis, and this is due to the fact that risk associated with natural hazard in Syria is caused by rainfall scarcity and/or fluctuations, such effects are likely to be minimal in our case since the farms considered are all wholly irrigated[2]. The availability of irrigation can help farmers coping with risk associated with rainfall fluctuation directly by enabling them to avail water into the fields in appropriate quantity at the right time, and indirectly by allowing the plants to optimise the use of some physical inputs such as chemical fertilisers.

Expected income is calculated as the farm average gross margin, which is simply the average total revenue minus the explicit costs only. Thus it contains the reward to land, family labour, and capital in addition to farm net profits. The costs of land, family labour and capital are considered sunk costs and so they do not affect the decision making process of farmers. This assumption would be restrictive if there were active markets for trading these resources. If an active market for land and employment existed, any farmer could rent part of his land and decide to spend part of her time engaging in off-farm employment. Then this would be considered in calculating the expected income of the farm by considering the explicit opportunity costs of land and family labour.

[2] - although the availability of local rainfall usually affects the irrigation costs, this is not true in our case since the availability of irrigation water does not rely on local rainfall.

In the long term, the objective of a farmer might be to utilize her family labour on the farm as long as the returns from work on the farm are greater than the opportunity cost. When such return becomes lower than the opportunity cost, the farmer is supposed to leave farming and seek employment elsewhere. However, this is only true under the conditions of perfect markets for labour which is never true in reality. Employment opportunities are always partially or totally precluded to farm family members, and so there will be always a difference between returns to labour and the corresponding opportunity cost, and farmers might be ready to accept remuneration to their labour less than the opportunity costs. This proposition is supported by several facts about DERAHA. First, part-time farming is very limited; second, the area is still considered the main provider of seasonal agricultural employment in the Country; third, sharecropping is very common in the region which is considered an effective response to market failures, especially failures related to factors' markets.

All farming activities included in the model are described by their requirements of land, labour, irrigation water, rental machinery costs and physical inputs. Fixed coefficients are assumed and so no economy to scale is considered. Although some farms have also some livestock activities, we ignored them in this model since their relevance for income generation for the farm family is very small and can be neglected as they are mostly raised for home consumption. Moreover, when livestock activities are relevant for income generation, they are not connected to other farm activities and can be considered off-farm activities[3].

The model distinguishes between a cropping activity and a product although in our case each cropping activity produces only one product. However, there is a case in which two cropping activities produce one same product (autumn and winter sugar beet crops produce the same product of sugar beet). Therefore, coefficients of yields are related to both cropping activities and products.

The model maintains the possibility to hire labour at a given rate wage when family labour is not enough to pursue all faming activities during some periods. Farms are also described by their monthly availability of land, family labour, and irrigation water. In addition, irrigation water sources and irrigation techniques pursued on the farms are essential characteristics of their structures.

The availability of machinery could be an essential feature of a farm structure since its availability may have consequences on the costs' structure. Then it may be one criterion that should be used in farms' classification into representative farming systems. However, due to lack of data at the individual farm level, we assume that all farms rent machinery to perform agricultural operations. This assumption is justified by the fact that the number of farms having tractors is very small. The secondary data sources show that the share of the number of tractors in DERAHA relative to the number of farms did not exceed 4% in 2007, and it was less than 3.5% in 2005, the reference year of the research (MAAR statistical abstracts). In addition, the study survey has uncovered the presence of an active market that provides machinery services at competitive prices though specialised agents.

3.1.1. Extensive assumptions on the definition of resource constraints

Fixed resources are land, irrigation water, family labour, and all other private factors that cannot be acquired in the time span analysed in addition to the public factors such as roads and extension services and other exogenous features such as weather and distance from markets. The possibility of these resources to be constraining in the agricultural sector depends very much on their total availability in the economy and the functioning of their markets.

In the context of Syrian economy, the market of casual agricultural labour is said to be well functioning according to the findings of a previous study. It is stated that labour organization and mobilisation functions according to local and non-local demands. This function is performed by

[3] - some farmers have relatively large sheep flocks, but the sheep are not integrated with the other farm activities because these farmers rely on concentrates to feed the sheep or they send them to join big flocks going to graze in the large pastures.

traditional contractors, the C*haweshes,* who pool agricultural labour (mainly female) in areas where there is excess supply of labour and make it available in different governorates according to market demand (Forni 2001). This suggests that labour is not a constraining resource in the context of Syrian agriculture. In case family labour is not sufficient to perform a specific operation, the possibility to hire labour is quite high.

However, the possibility that irrigation water is a scarce resource in the Syrian agriculture seems to be quite high. This has been proved by previous studies and working papers, stating that most water basins in Syria experience water deficit mainly due to intensive water use in agriculture that uses up to 80% of the total water use of the Country (Ortega & Sagardoy, 2001) (NAPC 2005a). In addition, the study survey findings have uncovered the importance of the available irrigation water on farmers' decision making. This is very true for the cultivation of summer crops which cannot be grown under the Syrian climatic conditions without irrigation, but it is also true for the cultivation of winter crops in many parts of the Country (almost all parts of DERAHA) if reasonable yields are to be obtained.

Some other studies highlight the importance of cash capital as an important constraining resource (Wattenbach 2006). This point is also supported by the findings of the study survey which investigated two main reasons for this constraint. The first one is related to the credit policy which favours the so-called strategic crops particularly wheat, cotton and sugar beet. Farmers who cultivate these crops have relatively easy access to credit provided by the Agricultural Cooperative Bank (ACB). This encourages farmers facing a cash constraint to cultivate these crops. The other reason results from market failure for agricultural credit when farmers fail to repay earlier credit to the ACB, making them excluded from formal credit trough the ACB, leading them to depend on informal sources of credits, which are quite expensive suggesting cases of abuse by traders and input providers (refer to **sections 2.3.3** and **2.3.5**).

The above discussion leads us to deduce that many poor farmers continue to grow the so-called strategic crops not only due to their profitability, but also because credit policy and credit market favour these crops. Then farmers who can grow other crops (such as fruits or vegetables) in relatively large quantities should be those who do not face any cash constraints, or those who face prohibitive constraints to the production of some or all strategic crops. It is then the aim of this research to test for this assumption (the presence of cash constraint) and its consequences on farmers' behaviour and their decision-making process.

3.1.2. Extensions on technical and policy-imposed constraints

Other technical constraints are these imposed by the agrarian rotations required for the cultivated crops, and they are different from one area to the other due to differences in prevailing cropping patterns in the Country, which is due to differences in the availability of resources; in government policies, and in climatic conditions. In DERAHA, however, agrarian rotations are simple. According to the survey findings, farmers follow rotations advised by the technical experts of the local agricultural departments. They divide the crops into cereals (wheat and barley) and non-cereals. The scientific basis of the rotation states that it is not advisable to grow any of the non-cereal crop two sequent times in the same land plot. Otherwise, some pests and diseases may develop causing damage to the relevant crop, or reducing its yield significantly. Therefore, the rotation constraint is that the combined area of the non-cereal crops is equal to or less than the combined area of the cereal crops.

One might think of the cash constraint discussed above to be a policy-imposed as it is very much affected by the government credit system. However, in this section, we only consider the constraints that are directly caused by government policy, which does not apply to the cash capital case. In this context, 'directly caused' means government actions that directly affects the decision making of farmers on 'what to produce' and so the types of crops that can be grown and on 'how much' and so the area cultivated under each crop. This is caused by the licensing system of the annual agricultural plan set and approved by the MAAR (**section 2.2.2**). This licensing system is imposed in DERAHA on cotton and sugar beet. It imposes a limit to the maximum area a farmer can cultivate under a particular crop in order to receive the official price for all of his/her output, which is said to be much higher than its international counterpart if free market conditions were prevailing. The way this licensing policy is implemented in reality is different according to the crop and the institutions involved in the implementation (**section 2.2.3**).

3.2. Description of the basic elements of the model

The mathematical programming model for each representative farming system can be described by the following equations:

Max $CE = GM - 0.5 * Rac * Var$ [3.1]

Where:

$GM = R - VC$ [3.2]

$Var = \sum_j \sum_k Q_j Q_k \sigma_{jk}$ [4] [3.3]

$Q_j = \sum_c \sum_i \sum_w X_{c,i,w} * Y_{c,i,j}$ [3.4]

$R = \sum_j Q_j * Ep_j$ [3.5]

$Ep_j = \sum_n Ps_{j,n} * prob_n$ [3.6]

$\sigma_{j,k} = \sum_n (Ps_{j,n} - Ep_j) * (Ps_{k,n} - Ep_k) * Prob_n$ [3.7]

$VC = Fc1 + Fc2 + Ic + Mc1 + Mc2 + Lc + Wf * L * Pn$ [3.8]

$Fc1 = \sum_s \sum_f \sum_i \sum_w X_{s,i,w} * In_{f,s,i} * Pr_{f,s} * (1 + Ir)$ [3.9]

$Fc2 = \sum_o \sum_f \sum_i \sum_w X_{o,i,w} * In_{f,o,i} * Pr_{f,o}$ [3.10]

$Ic = \sum_c \sum_i \sum_w X_{c,i,w} * Dq_{c,i,w} * Dp$ [3.11]

$Mc1 = \sum_t \sum_s \sum_i \sum_w X_{s,i,w} * Mp_{s,i,t} * (1 + Ir)$ [3.12]

$Mc2 = \sum_t \sum_o \sum_i \sum_w X_{o,i,w} * Mp_{o,i,t}$ [3.13]

$Lc = \sum_t Hlab_t * Wh$ [3.14]

---

[4] - if *X* and *Y* are random variables, then the variance of their sum *Var[X+Y] = Var[X] + Var[Y]+2Cov[X,Y]*. Equation [3.3] is a generalization of this basic rule (Hazell & Norton 1986).

Subject to:

$\sum_c \sum_i \sum_w X_{c,i,w} * Lr_{c,t} \leq L$ [3.15]

$\sum_{ex} \sum_i \sum_w X_{ex,i,w} * Lr_{ex,t} \leq 0.5 * L$ [3.16]

$\sum_c \sum_i \sum_w X_{c,i,w} * Labr_{c,i,t} \leq Flab_t + Hlab_t$ [3.17]

$\sum_c \sum_i \sum_w X_{c,i,w} * Watr_{c,i,t} \leq Wat_t$ [3.18]

$\sum_c \sum_f \sum_i \sum_w \alpha_c * X_{c,i,w} * In_{f,c,i} * Pr_{f,c} + \sum_t \sum_c \sum_i \sum_w \alpha_c * X_{c,i,w} * Mp_{c,i,t} + \sum_c \sum_i \sum_w \beta_c * X_{c,i,w} * Dq_{c,i,w} * Dp+tHlabt*Wh\leq Cap$ [3.19]

$\sum_c \sum_w X_{c,sprink,w} * Lr_{c,t} \leq Sp * L$ [3.20]

$\sum_c \sum_w X_{c,drip,w} * Lr_{c,t} \leq Dr * L$ [3.21]

$\sum_c \sum_i X_{c,i,well} * Lr_{c,t} \leq Pw * L$ [3.22]

$\sum_c \sum_i X_{c,i,net} * Lr_{c,t} \leq Pn * L$ [3.23]

$\sum_c \sum_i X_{c,i,river} * Lr_{c,t} \leq Ri * L$ [3.24]

$\sum_i \sum_w X_{cotton,i,w} * Lr_{c,t} \leq cotls$ [3.25]

$\sum_i \sum_w X_{autsugar,i,w} * Lr_{c,t} \leq asugls$ [3.26]

$\sum_i \sum_w X_{winsugar,i,w} * Lr_{c,t} \leq wsugls$ [3.27]

$\sum_i \sum_w X_{barley,i,w} * Lr_{c,t} \geq bareq$ [3.28]

$Wuse = \sum_t \sum_c \sum_i \sum_w X_{c,i,w} Watr_{c,i,t}$ [3.29]

$TLuse = \sum_t \sum_c \sum_i \sum_w X_{c,i,w} Labr_{c,i,t}$ [3.30]

$HLuse = \sum_t Hlab_t$ [3.31]

$FLuse = TLuse - HLuse$ [3.32]

Where the definitions of the notation used in the previous model are given as follows:

Terms related to the objective function

CE: is the measure adopted for the expected utility of farm income and it is assumed to be the certainty equivalent of the corresponding expected farm income (SP).

GM: is the gross margin (net revenue) which is the measure of the expected farm income (SP).

Var: is the variance of farm income (SP)

R: is the total farm revenue (SP)

Ep_j: is the expected price of j-th product (SP)

Q_j: is the total output of the j-th product (kg)

Q_k: is the total output of the k-th product (kg)

σ_{jk}: is the covariance of prices of the j-th and k-th products (SP)

VC: is total variable costs (SP)

$Fc1$: is the cost of seeds, fertilisers and other chemicals for strategic crops (SP)

$Fc2$: is the costs of seeds, fertilisers and other chemicals for other crops (SP)

Ic: is the costs of pumping water calculated as the costs of diesel (SP)

$Mc1$: is the costs of renting machinery for strategic crops (SP)

$Mc2$: is the costs of renting machinery for other crops (SP)

Lc: is the costs of hired labour (SP)

$X_{c,i,w}$: is the level of cropping activity to be chosen in the optimal solution, it represents the area of c-th crop irrigated by the i-th irrigation technique and the w-th irrigation source (ha).

$X_{s,i,w}$: is the level of cropping activity for strategic crops, it is equivalent to $X_{c,i,w}$ when the c represents only the subset of strategic crops (ha).

$X_{o,i,w}$: is the level of cropping activity for other (non-strategic) crops, it is equivalent to $X_{c,i,w}$ when c represents the subset of the other (non-strategic) crops (ha).

$Hlab_t$: is the amount of labour hired in the t-th month (hour)

Parameters applied to all farming systems

$Lr_{c,t}$: the unit requirements of land for the c-th cropping activity in the t-th month (ha/month)

Wf: irrigation fee (SP/ha)

Ir: is the interest rate for credit obtained by the ACB (%)

Dp: is the price of diesel input which unique and set centrally by the GOS (SP/litre).

$Ps_{j,n}$: is the price of the j-th product when the n-th state of nature takes place (SP/kg)

$Prob_n$: is the probability that the n-th state of nature takes place (%)

$Pr_{f,c}$: are the input prices, they define the price of f-th input used for c-th cropping activity (SP/kg)

Wh: is the wage rate for hired labour (SP/hour).

$Flab_t$: is family labour availability in the t-th month (hour/month)

Wat_t: is irrigation water availability in the t-th month (cubic meter/month)

α_c: is the coefficient of cash anticipation for the c-th cropping activity applied for inputs whose costs are covered by the official credit system (%).

β_c: is the coefficient of cash anticipation for the c-th cropping activity applied for inputs whose costs are not covered by the official credit system (%).

$Pr_{f,c}$: is the price of the f-th input of the c-th cropping activity (SP/kg)

Parameters differentiated according to different mantikas and agro-climatic zones

$Y_{c,i,j}$: is the unit yield coefficient, it defines the amount of j-th product that can be obtained from one unit c-th activity when the latter is irrigated by the i-th irrigation technique (kg/ha).

$Watr_{c,i,t}$: are the unit requirements of irrigation water for the c-th cropping activity and the i-th irrigation technique in the t-th month (cubic meter/ha/month).

$Labr_{c,i,t}$: are the unit requirements of labour for the c-th cropping activity and the i-th irrigation technique in the t-th month (hour/ha/month).

$In_{f,c,i}$: are the unit requirements of physical inputs namely seeds, fertilisers and other chemicals for the f-th input, c-th cropping activity and i-th irrigation technique (kg/ha)

$Mp_{c,i,w}$: are the unit costs of rented machinery for the c-th cropping activity, the i-th irrigation technique and the w-th irrigation water source (SP/ha).

$Dq_{c,i,w}$: are the unit requirements of diesel necessary for pumping irrigation water for c-th cropping activity, i-th irrigation technique and w-th irrigation souce (litre/ha).

parameters given at the farm level

L: is the farm size (ha)

Cap: is cash availability at the beginning of the agricultural year (SP)

Pw: is a dummy variable that takes the value of one if the farm is irrigated from private wells, and zero otherwise.

Pn: is a dummy variable that takes the value of one, if the farm is irrigate from public nets, zero otherwise.

Ri: is a dummy variable that takes the value of one if the farm is irrigated from a river, zero otherwise.

Sp: is a dummy variable that takes the value of one if the farm has sprinkler irrigation technique, zero otherwise.

Dr: is a dummy variable that takes the value of one if the farm has drip irrigation technique, zero otherwise.

$Cotls$: defines the maximum area that can be cultivated with cotton for each farm according the licensing system (ha).

$Asugls$: defines the maximum area that can be cultivated with autumn sugar beet for each farm according the licensing system (ha).

$Wsugls$: defines the maximum area that can be cultivated with winter sugar beet for each farm according the licensing system (ha).

$Bareq$: defines the minimum area that must be cultivated with barley to have enough feed for livestock activities (ha).

Rac: is the absolute risk aversion coefficient

Variables calculated from the solution

$Wuse$: the amount of water used at the farm level (CM)

$TLuse$: the amount of total labour used at the farm level (hour)

$HLuse$: the amount of hired labour used at the farm level (hour)

$FLuse$: the amount of family labour used at the farm level (hour)

Equation [3.1] represents the objective function to be maximised. Equations from [3.2] to [3.14] represent the calculations of the terms of the objective function. The gross margin (net revenue) of the representative farm is calculated in equation [3.2]. Equation [3.3] calculates the total variance of the farm income, while equation [3.4] calculates the total output produced for each product. Since the farm's net revenue is the total revenue minus variable costs, the total revenue of the farm is calculated by equation [3.5] while the total variable costs are calculated through equation [3.8]. Equation [3.6] calculates the expected price for each product to be used in calculating the revenue, while equation [3.7] calculates the variance-covariance matrix of the products' prices, which is used in the calculation of the variance of the total farm's income.

Equations from [3.9] to [3.14] represent the components of the variable costs of equation [3.8]. Equation [3.9] calculates the costs of seeds, fertilisers and the chemicals for the crops for which such inputs are covered by the credit of the ACB, while equation [3.10] calculates the costs of the same inputs but for crops for which such inputs are not covered by the credit system. Equation [3.11] calculates the costs of pumping the irrigation water, which is simply the quantity of diesel used for each cropping activity times the price of diesel. Equation [3.12] and [3.13] repeat the same calculations of [3.9] and [3.10] having the costs of the physical inputs replaced by the costs of rented machinery.

Inequalities from [3.15] to [3.28] describe the technical constraints of the model. Some of these constraints are related to the limited availability of a resource, while others are related to the technical and structural aspects of the representative farming system. Inequality [3.15] describe the land constraint, it states that the total area occupied by all cropping activities in a certain month must not exceed the total farm size. Inequality [3.16] describes the constraint imposed by agronomic rotation pursued by farmers, there is a group of crops that should not be cultivated in the same land plot two subsequent times; otherwise pests and diseases will grow and output will fall. This group is denoted by the subset (ex) as above. Therefore, the total area occupied by these crops in each month must not exceed 50% of the total farm size.

Inequality [3.17] represents the constraint related to labour, it states that the total labour use in each month must not exceed the total availability of family labour in that month plus a term ($Hlab_t$) that allows the hiring of additional labour if needed. Inequality [3.18] describes the constraint related to the availability of irrigation water, so that total water use in a month must not exceed water availability in that month.

Inequality [3.19], on the other hand, describes the constraint of cash availability which is more complex than the other constraints. The inequality makes use of two parameters that we call coefficients of cash anticipation. These coefficients are calculated based on the length of the biological cycle of the cropping activities considered. The coefficient associates a numerical value to each cropping activity, which reflects the length of its biological cycle. Therefore, as the latter gets longer the value gets bigger. The values are calculated by dividing the length of the biological cycle for each cropping activity in months over the total number of the months in the year. However, the coefficients are classified in two groups α_c and β_c, in which the values of the coefficients for most crops are identical. The only difference regards the coefficients' values associated with some strategic crops for which the costs of physical inputs and rented machinery are covered by the credit system, and so farmers do not have to worry about cash to cover these costs. In this case, the values of α_c associated with cotton, wheat, sugar beet and barley are all equal to zero. As a result, the inequality states that the total amount of cash capital needed to finance the purchases of inputs and the agricultural operations must not exceed the amount of cash capital available at the beginning of the agricultural year.

It could be argued that a better way to model the cash capital constraint would be through an equation stating that the total amount of cash capital used in a month must not exceed the cash capital available in that month, taking into account all cash flows of the farm. However, such way of modelling requires a very detailed data on farms' cash flows that are not available and are too expensive to collect given the limited resources available to this research. Nevertheless, the way cash capital constraint is modelled enables us to evaluate the possible impact that the current credit policy has on the decision making of farmers as we will see in the next chapter.

Inequalities from [3.20] to [3.24] aim at describing some technical aspects of the representative farms. Inequality [3.20] is activated only when the representative farm has a sprinkler irrigation net (when the dummy *Sp* takes the value of one), while inequality [3.21] is activated when representative farm has a drip irrigation net (when the dummy *Dr* takes the value of one). Inequalities [3.22], [3.23] and [3.24] are activated when the representative farms are irrigated from a private well, public network and river respectively.

Inequalities [3.25], [3.26] and [3.27] describe constraints imposed by policy interventions. Inequality [3.25] states the maximum area that can be cultivated with cotton while the other two describe the maximum area that can be cultivated with sugar beet (autumn and winter respectively) in each representative farm.

Inequality, [3.28], states the minimum area that must be cultivated with barley. This inequality is justified by the fact that wheat and barley are very similar in terms of technical requirements, cost structure, and some aspects of policy intervention. The only difference is in their pricing policy in which the price of wheat is about 20% higher than that of barley. The secondary data sources suggest that only some farms produce barley in limited quantities. The survey findings prove that these farms do not grow barley for sale; they rather use it to feed their livestock (mainly sheep).

The best way of considering this fact in our mathematical programming model is to include the sheep flocks in the analysis. However, this is beyond the scope of this research due to time and resource constraint. Including sheep flocks in the analysis is not expected to add significant value to our model concerning the measurement of the agricultural policy impact on water use and farms' incomes. This is because sheep herds consume negligible amounts of water in comparison to the consumption of the other crops, and their output are mostly used for home consumption. To solve this problem, we assume that farms producing barley do so for the market. However, if we solve the model without this constraint, no barley will appear in the optimal solution and its area will be occupied by wheat instead. Therefore, we set a minimum area to be planted with barley, which is translated in our model by setting a constraint stating that the area planted with barley to be equal to or greater than the observed area of barley.

Finally, equations from [3.29] to [3.32] are not part of the model, they are rather used to calculate water and labour use at the representative farm level. Equation [3.29] calculates water use, while equations [3.30], [3.31], and [3.32] calculate total labour use, hired labour and family labour use respectively.

3.3. Farming systems' classification

Applying the analytical method described in the previous section for the sake of policy analysis requires combining it with farms' representation. Therefore, the irrigated farms of DERAHA must be classified in a relatively small number of representative farm types. Such a classification should take the following criteria into consideration:

1. the boundaries that separate different administrative governorates and districts (mantikas[5]). This is useful because data collection by governmental agencies is mainly based on these boundaries. Such data (yields) reflect in many cases significant differences among different mantikas or governorates, making grouping of farms located in different governorates or mantikas in one farm type not meaningful without getting data on the individual farms' level.
2. the boundaries that separate agro-ecological zones. This is necessary as many data collected by governmental agencies are also based on these boundaries. In addition, different agro-ecological zones have important effects on irrigation requirements (i.e. water use) of the cultivated crops in different areas since these zones are determined according to the

[5] - mantika is the second administrative level in Syria after governorate which is the highest administrative level. They correspond to 'provincia' and 'regione' respectively in Italy.

average level of rainfalls. In general, the higher the rainfall the lower the irrigation requirements, especially for winter crops that can make use of rainfall water.

3. the sources of irrigation water, which can be classified in three main types in Syria: private wells, public nets, and rivers. Water source usually affects water cost, which, in turn, affects the level water use and the level of farms' incomes.
4. the farm size (e.g. small, medium, or large), which may have an impact on the economy of scale, affecting, in turn, the overall profitability of the farm as well as its capability to innovate and adopt new technologies.
5. the cropping patterns, as different farms might grow different crops reflecting specialisation. This affects irrigation water use and farms' incomes as different crops have different irrigation requirements and generate different gross margins.
6. the irrigation techniques, which can be generally categorised into flood, drip, or sprinkler techniques. They clearly have an impact on water use, since modern techniques tend to save water in comparison with the flood traditional technique. In addition, modern irrigation schemes affect the composition of production costs which influence the decision making of farmers. They are also considered more income generating since they give higher yields coupled with lower variable costs.

Hence, we aim to construct a model that represents the aggregate behaviour of the irrigated farms' sector in DERAHA through a bottom-top approach, that is to start modelling the behaviour of individual farming systems that allows us estimating the cropping areas and the derived demand for water of each individual farming system. Then we obtain the aggregate cropping areas and water demand of the farming sector in the region by calculating a weighted sum of cropping areas and water demand of all individual farming systems, in which weights are chosen to represent the relative contribution of each representative farming system to the region's total. These aggregate water demand functions will be used in assessing the incidence of possible alternative policies on water use. In addition, by assuming that incomes of the farming households generated outside the agricultural sector holds unchanged, farms' gross margins and certainty equivalents will be used as an indicator of income level and stability by simulating the impact of some expected policy reforms on them.

Due to the lack of data at the individual farm level, we performed the classification through the following process of disaggregation:

- The entire irrigated area of each governorate in DERAHA is divided according the administrative boundaries.
- The irrigated area in each mantika is divided according to the agro-ecological zones.
- The irrigated area in each agro-ecological zones is divided according to irrigation sources
- The irrigated area from different irrigation sources is divided according to irrigation techniques.

Therefore, farm types are distinct according to their location (mantika), agro-ecological zone (1-5), irrigation source (private wells, public networks, or rivers), and irrigation technique (flood, sprinkler, and drip). The lack of data also did not allow us to take into account farm sizes and cropping patterns during the classification. Therefore, we assume that these two criteria do not affect farms' structure, which is an assumption supported by several observations. First of all, cropping patterns and areas of farms in DEHARA are very similar at the mantika level. So taking the location of farms at the mantika level into consideration in the classification is enough to consider the two criteria. Moreover, farm size has a small impact on technology at the farm level in DERAHA as it is shown in a previous study (Wattenbach 2006).

3.4. Description of data

The data used in the farms' classification are available in the database of the National Agricultural Policy Center (NAPC: www.napcsyr.org) and the Statistical Abstracts of the Ministry of Agricultural and Agrarian Reform (MAAR 2005). These data represent the total irrigated area of DERAHA, but then divided according to mantikas, agro-climatic zones, irrigation water sources, and irrigation techniques. Now we move to describe the data we used to construct the mathematical programming model for each farm type.

3.4.1. Farm fixed resources

Farm size and cropping patterns

The definition of the average farm size for each farming typology is determined by dividing the total cultivated area at the last level of disaggregation (the irrigation technique level) by the number of farms. Due to the absence of official data about the number of farms at this level, the estimates of the local experts (the heads of agricultural departments at the mantika level) are used. Then the total areas of the cultivated crops is divided by the number of farms to obtain the average cropping pattern of each farm type. The crops' areas are taken from NAPC database.

Water availability

Water availability at the farm type level is fully determined through the findings of the study survey. Its determination depends on irrigation water sources. When the source of water is private wells, water availability is estimated based on the maximum capacity of the pump-sets that the farmers have. So water availability in each month is the same across the year assuming that farmers have deep wells that are reliable along the year. Of course, there are many farmers who have shallow wells that are unreliable in bad rainfall years. These farms are not considered to be using wells as the main source of irrigation. They are categorised under other types because they are assumed to use wells as supplementary irrigation source.

When irrigation source is public nets, farmers' access to irrigation water is manipulated by governmental agencies. In this case, water availability in each farm is estimated according to a pre-determined schedule set by the Ministry of Irrigation (MOI) in which every farmer has access to water for some time per week during certain months of the year. In cases where a river is the main source of irrigation, water availability is estimated in a similar way to that of public networks, since farmers using river water for irrigation are organised in consortiums which work under the supervision of the MOI who sets a schedules for each consortium.

Family labour availability

Due to the absence of detailed data at the level of individual farms, family labour availability is assumed differently according to the local conditions observed during the study survey. In HAG where almost all farms are managed directly by sharecroppers, we treat labour of the sharecroppers' households as family labour since it has all of its characteristics. Then the numbers of family labour available are calculated by dividing the total farm size by 3, assuming that each 3 hectares requires one full-time labourer, then the resulting number is multiplied by 150 which is the number of working hours per month. In Al-RAG, where all farms are managed directly by the owners, we assume that each family devotes 2 members full time and one part-time (50% of its time). The only exception is the mantikas of Tal-Abiad, where farms are mostly managed by investors from outside the region, here we assume only one family labourer full time. In DEG, where farms are also managed by owners, we assume that each family dedicates two members full time only[6]. Although some may argue that in RAG and DEG, families may be able to dedicate more family labour, we have observed from the survey that in general other family members, due to the limited size of their farms, are already involved in other activities: e.g. livestock (mainly sheep), public employment, working abroad, etc.

Irrigation methods

The observed irrigation schemes are flood, sprinkler, and drip. These techniques are presented in the model using dummy variables taking values of zero or one. These dummies represent an 'investment switch' so they allow making simulations of switching farms from the flood scheme to

[6] - these numbers are assumed based on the estimates of local experts working at the Departments of Agriculture in the relevant governorates.

drip or sprinkler techniques by the changing the value of the variable from zero to one. In this regard, the model recognises that some irrigation techniques are not suitable for some crops, for example, drip scheme is not suited for irrigating wheat and barley. In addition, the model recognises the possibility of switching wheat and barley (but not cotton) to the rainfed mode. This is because wheat and barley can be grown without irrigation, but resulting lower yields, but it is impossible to grow cotton in Syria without irrigation. However, the model does not include the fixed costs associated with the investment switch since only variable costs are considered.

3.4.2. Technical requirements and coefficients

Irrigation water requirements

The irrigation requirements of the various crops are determined at the agro-ecological zone level in each governorate by month (GCASR 2006). However, these data are adjusted in light of the survey findings because farmers use more water for irrigation than indicated in the secondary source. The numbers indicated in the official source are calculated using some equations reflecting the 'optimal' irrigation requirements rather than the real ones[7], and they are only used as a reference point.

Irrigation requirements are different by governorate, agro-ecological zone, crop, irrigation techniques and month. The differences in terms of different irrigation techniques are based on assumptions drawn from the discussions with the local experts of agricultural departments in DERAHA. It is assumed that sprinkler and drip techniques save 10% and 20% with respect to flood traditional one, although the water saved using these two modern techniques are much higher in the 'optimal' situations. The lower saving percentages result from the technical difficulties that farmers face in using the modern techniques. This has implications for policy actions and is discussed later in the report in more detail. Of course, irrigation requirements of rainfed crops are zero.

Labour requirements

Labour requirements for each crop are mainly obtained from a secondary source at a monthly level (MAAR 1994). However, the labour requirements for labour demanding operations (such as cotton and sugar beet harvesting) are modified in light of the survey findings to reflect the differences in yield among different farm types, since the numbers of the secondary source are averages at the national level. This is important because harvesting forms the main labour requirements for cotton and sugar beet and is heavily affected by yield. The adjustment is based on a simplifying assumption that the labour required for harvesting is a linear function of yield.

Physical inputs

These data include the crops' requirements of chemical fertilisers and seeds. They are three kinds of chemical fertilisers used for all crops: nitrogen, phosphate, and potash. Their required quantities differ depending on the crop only for irrigated cultivation. If the crops are rainfed, they are then different according to the agro-ecological zones too, due to the differences in average rainfall and crops' responses to fertilisation.

Crops' yields

Crops' yields differ according to mantikas, agro-ecological zones, and irrigation methods for irrigated crops. The numbers are obtained as averages from the database of the NAPC. Due to the absence of data on the yields of crops irrigated by drip and sprinkler schemes, their yields are estimated based on the discussion with the local experts. It is assumed that sprinkler and drip techniques increase the yields by 10% and 15% respectively with regard to flood technique. This takes into consideration that some techniques are not suited for some crops; for example, drip technique does not suite the irrigation of wheat and barley. In this case, yield is assumed equal to zero.

For rainfed crops, yields are calculated from the NAPC database as the average yields for the last

[7]- this information is obtained from Mr Mamoun Kanafani, the officer who is officially responsible about delivering the abstract of water requirements in GCASR.

seven years only at the level of agro-ecological zones. This averaging is just an attempt to minimise the effects of fluctuations from year to year as a result of rainfall fluctuations.

3.4.3. Prices of inputs and outputs

Prices of outputs

It is mentioned above that some crops have fixed prices, which are cotton and sugar beet whose prices are used in the model taking into account that the prices received by farmers are slightly different from the official ones reflecting differences in quality. Therefore, the average prices calculated at the national level and reported in the annual agricultural abstract of the MAAR are used. For crops that have floor prices, which are wheat, barley, lentil, and chickpea, we assume that their floor prices are the effective ones in the decision making process of farmers.

Generally speaking, the choice of prices is not an easy task to perform for crops whose prices are determined by the interactions of supply and demand without a direct intervention from the Government. This is very much true since these prices may change from year to year according to market conditions. Such variability in the prices is the only cause of variability of farms' incomes in our model, and caution is necessary in choosing the method to model them. In our case, we make an assumption on their statistical distribution. The assumption we adopt in this thesis is that of lognormal distribution which has several advantages for our case. First, such distribution can be represented by its first and second moments as the case of normal distribution; however, it has an advantage over the latter since variables of lognormal distribution do not take negative values, which is important in our case since negative prices have no sense. Second, lognormal distribution is very consistent with price variability. On one hand, the values of the variable cannot take values less than zero as mentioned right above, and it is very reasonable that prices may go very high if a sudden supply shock is materialised on the other hand.

In line with this assumption, we generate a matrix of prices in which prices are specified by product and state of nature. We use the method of *Gauss-Hermite quadrature* as described in Judd (1998) to create a price series for each product assuming the presence of ten states of nature, to which a specific probability is attached. To achieve this, a time series for each product price is selected and deflated using domestic wholesale price index, then they are detrended when a time trend is observed. After that, their logarithm is calculated to create series of logarithm values, from which we calculate the mean and variance for each series. Then we use MATLAB software to calculate the price distributions using the following command:

```
[x, w] = qnwlogn(n, mu, var)
```

Where:

`x`: represents the series of the variable values

`w`: represents the series of probabilities attached the variable values

`n`: is the number of states of nature (it is equal to ten in our case)

`mu`: is the mean of the logarithm values of the series

`var`: is the variance of the logarithm values of the series.

`qnwlogn`: is the expression used by MATLAB to calculate the series of variable values (x) assuming that the latter has a lognormal distribution.

This formula generates a series of ten prices for each product with their associated probabilities assuming ten states of nature. **Table 3.1** shows the price matrix used in the model with the associated probabilities for each state of nature. It is of interest to notice that prices of strategic crops are constant regardless of the state of nature since their variance is equal to zero.

Table 3. 1. Price matrix of the model products with the associated probabilities

State of nature	1	2	3	4	5	6	7	8	9	10
wheat	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50
barley	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
maize	6.83	7.54	8.22	8.90	9.60	10.36	11.18	12.11	13.19	14.57
lentil	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
chickpea	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
Broad bean	18.30	20.18	21.95	23.73	25.58	27.55	29.69	32.10	34.91	38.49
soybean	14.24	15.57	16.81	18.05	19.33	20.69	22.16	23.79	25.69	28.09
Sugar beet	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
sesame	18.77	22.11	25.45	29.00	32.89	37.25	42.24	48.13	55.40	65.26
peanut	14.22	16.50	18.74	21.09	23.63	26.45	29.64	33.36	37.89	43.94
cumin	25.08	30.00	35.00	40.37	46.33	53.08	60.91	70.27	81.97	98.06
cotton	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
Sum. watermelon	1.44	1.74	2.04	2.37	2.74	3.17	3.66	4.26	5.01	6.05
Aut. watermelon[8]	1.59	1.95	2.33	2.75	3.22	3.76	4.41	5.19	6.20	7.61
potato	1.84	2.49	3.23	4.12	5.20	6.55	8.27	10.54	13.69	18.55
tomato	1.46	1.92	2.42	3.00	3.69	4.54	5.58	6.93	8.74	11.46
eggplant	2.18	2.71	3.27	3.89	4.59	5.42	6.41	7.63	9.20	11.44
probability	0.000	0.001	0.019	0.135	0.345	0.345	0.135	0.019	0.001	0.000

Source: author elaboration

Prices of inputs

The prices of all kinds of chemical fertilisers and seeds of cotton, wheat, sugar beet and barley, are set administratively by the GOS through the ACB. For the seeds' prices of other crops, we use data collected at the farm level after cross-checking them with the local experts.

3.4.4. Labour wage

Labour wage in Syria is paid in a non-standardised way. It might be paid on a daily basis as in the case of weeding where the wage used to be 150 SP/day in 2005 (for a working day of six hours), or it might be paid according to the amount of work done as in the case of cotton harvesting (4.5 SP/kg). In addition, the labour wage might be different according to the task whether it easy or hard. To simplify the model, we use one standard labour wage per hour. This matter was discussed with the local experts as well as with the interviewed farmers. Based on that, we assume that labour wage was 25 SP/hour in the reference year, since it is the effective wage that farmers pay for hired labour in 95% of the situations according to the local experts.

3.4.5. Water costs and interest rate

Water costs are different according to water sources. Farms that depend on the public nets for irrigation pay an annual irrigation fee per hectare regardless of the amount of water used, this fee has been fixed at 600 SP/ha for winter irrigation only and it goes up to 3500 SP/ha when summer irrigation is also present as the situation in all irrigated farms of DERAHA. Some of the farms using public networks do not incur any operational costs to bring the irrigation water into the fields since it is driven by gravity, but others do incur such operational costs since the public canals may be far from the farms or because the irrigation networks are not constructed in a mode that supports gravity irrigation. On the other hand, farms who depend on private wells and rivers do not pay any fee, but they incur pumping costs which might be considerable.

Pumping costs are calculated by the model by multiplying the diesel requirements per crop per hectare by diesel price, which is set centrally by the GOS, the price was set at 7.4 SP/litre in the reference year, but in the model we use the effective price paid by farmers which is equal to 8 SP/litre to include the cost of transporting the diesel to the farm gate level. The diesel requirements are assumed to be different by crop, mantika, and agro-climatic zone, irrigation source and irrigation technique, and they are calculated based on the survey findings. However, since most

[8] - sum. Stands for summer while aut. Stands for autumn.

interviewed farms use only flood irrigation method, the costs of pumping using drip and sprinkler methods are calculated in light of some differences in irrigation requirements among different techniques (**section 3.4.2**).

Concerning the interest rate, we consider only credit that covers the costs of variable inputs and agricultural operations, which lies under the short-term credit according to the loan categories of the ACB, since our model takes into we consideration only variable (explicit) costs,. The ACB's interest rate for such credit differs according to whether the borrowers act individually or collectively. In 2005, the interest rate for the former was 5.5% while it was 4% for the latter, added to it in both cases 1% as a commission for the ACB making the effective interest rates 6.6% and 5% respectively. Due to lack of data at the individual farm level, it is impossible to distinguish individual farmers from collective ones, and so we assume a unique interest rate for all which is a weighted average of both previous ones. However, the weight used in the study is based on the author judgement from the fieldwork and is not based on an official figure.

3.4.6. Coefficients of cash anticipation

The coefficients of cash anticipation are defined in **section 3.2** above, here we just present them in the following table.

Table 3. 1. Matrix of coefficients of cash anticipation of cropping activities

Cropping activity	Coefficient of cash anticipation α_c	Coefficient of cash anticipation β_c
wheat	0.00	0.67
barley	0.00	0.63
Intercalary maize	0.38	0.38
Lentil	0.54	0.54
Chick	0.54	0.54
Broad bean	0.54	0.54
Soybean	0.33	0.33
Autumn sugar beat	0.00	0.83
Winter sugar beet	0.00	0.63
Sesame	0.29	0.29
Peanut	0.46	0.46
Cumin	0.54	0.54
Cotton	0.00	0.71
Autumn watermelon	0.33	0.33
Summer watermelon	0.29	0.29
Spring potato	0.50	0.50
Summer tomato	0.29	0.29
Summer eggplant	0.29	0.29

Source: author elaboration

As mentioned in **section 3.2**, these coefficients are calculated based on the length of the biological cycle of the cropping activities considered, by dividing the length of the biological cycle for each cropping activity in moths over the total number of the months in the year. However, values associated with some strategic crops (cotton, wheat, sugar beet and barley) are all equal to zero for coefficients' group $\boldsymbol{\alpha_c}$.

3.4.7. Other costs

<u>Rental machinery costs</u>

Many crops in DERAHA are highly mechanised. Wheat and barley are almost totally mechanised, where irrigation is the only manually performed operation. The situation is similar for cumin, chickpea, maize and lentil with the only exception that harvesting is performed both manually and mechanically. For cotton, machinery is used only for ploughing and tillage.

Almost all farmers in DERAHA rent machinery to perform these operations due to the active market for these services caused by the presence of specialised agents providing them. During wheat harvesting season, harvesters from Turkey are allowed to enter Syria to assist meeting the demand for this service.

Harvesting cost in DERAHA is paid on an output-percentage basis which is 5-6% of the production value. For rainfed crops, the costs of all machinery services are linked to yields, which are very much affected by rainfalls i.e. agro-ecological zones. However, only the harvesting cost is directly linked to yields (10% of the output value for wheat and barley and about 5-6% for lentil, 2-3% for cumin and 9-10% for chickpea), while the costs of other machinery services are paid on a per-hectare basis.

<u>Transportation and other costs</u>

These include the costs of transportation of the output (to the market or governmental delivery centres), costs of liquid chemicals, packing materials, cost of oil and repairs for the pumping sets, etc. These costs form a small proportion of the total variable costs, and they differ only according to the crop for irrigated farming, but also according to yields for rainfed farming. Since yields of rainfed crops are considered only different at the agro-ecological zone level, they are differentiated only by agro-ecological zone.

3.5. Solving and validating the model

Using mathematical programming as a predictive tool requires validating and calibrating the model. Predicting how the optimal solution would change due to a change in any parameter is only possible after verifying that the model is able to replicate the observed data that demonstrate farmers' choices and decisions.

The software used in setting up, solving, calibrating and simulating our mathematical programming model is the General Algebraic Modelling System (GAMS). All data are entered into GAMS and organised in four separate sheets. The first one (model) includes the basic elements of the model, the second (region) includes all data that apply to all farm types which are the prices of outputs and physical inputs, coefficients of cash anticipation, land requirements for all crops as well as scalar parameters such as labour wage rate, interest rate, and irrigation fee. The third (mantikas) includes all data that are different at the mantika level. These are crops' yields, physical inputs requirements, rental machinery costs and diesel requirements for pumping irrigation water. The forth and last sheet (farms) includes all farm fixed factors, plus data on farms' typologies according to their locations in mantikas and agro-climatic zones, and according to their source of irrigation and irrigation techniques pursued. In addition, data on maximum (or minimum) areas of certain crops due to policy constraints or to assumptions are included in the last sheet. At the end of the sheet, a table of the observed cropping patterns at the farming system level is inserted to help performing the calibration process. The GAMS model and data used in the analysis are available in **Appendix I**.

Two kinds of observed data are used as references to validate the model, which are cropping patterns at the individual farming system level and water use at the governorate and the hydraulic basin level. The validation aims to get the results of the optimal solutions on cropping patterns and water use as close as possible to their observed counterparts. The parameter used to achieve this purpose is the risk aversion coefficient whose choice will be discussed now in detail.

With reference to the objective function of our model (equation [3.1]), it has been already said that this function represent maximising expected utility trough maximising certainty equivalent. All data needed to calculate the objective function are available except data on the risk aversion coefficients. In our model we assume that utility functions of farmers are characterised by constant absolute risk aversion. Therefore, these coefficients are assumed to reflect farmers' attitudes towards risk, the higher is the coefficient the more risk averse the farmer is.

Table 3. 2. Comparison between observed data and model results for key variables

	Observed data	Solution	% change
Water use (million CM)			
HAG	3440	3595	+4.51
RAG	3119	3146	+0.87
DEG	2374	2369	-0.21
Wheat area (ha)			
HAG	344500	341408	-0.90
RAG	132627	135729	+2.34
DEG	101648	106822	+5.09
Cotton area (ha)			
HAG	85412	87447	+2.38
RAG	58959	60147	+2.01
DEG	25943	25106	-3.23
Sugar beet area (ha)			
RAG	4750	4958	+4.38
DEG	4338	4132	-4.75
Area of intercalary crops (ha)			
HAG	3332	3441	+3.27
RAG	15919	15664	-1.60
DEG	39318	41448	+5.42
Area of other winter crops (ha)			
HAG	13414	13396	-0.13
RAG	4001	3848	-3.82
DEG	6260	6515	+4.07
Total cropped area (ha)			
HAG	445094	445693	+0.01
RAG	219951	220347	+0.18
DEG	183954	184024	+0.04
Range of calibrated risk aversion coefficients			
HAG	0.001 – 0.005		
RAG	0.002 – 0.007		
DEG	0.001 – 0.004		
Coefficient of correlation (CC) between risk aversion coefficient and farm size in all DERAHA			-0.60
CC between risk aversion coefficient and farm size in all DERAHA except DEG			-0.80

Source: the study results, NAPC database, and GCASR (2006)

Several ways of estimating risk aversion coefficients have been so far proposed in literature. Here we adopt the method proposed by McCarl (2003) and by Hazell & Norton (1986), since it is consistent with basic assumption of the model and it is easy to perform. It is based on estimating the risk aversion coefficient such that the difference between the observed behaviour and the optimal solution is minimised. This requires solving the model for each farm for several values of risk aversion coefficient, and then we pick the value that gives the cropping mix closest to the observed one. By doing so, we generated a set of risk aversion coefficients; one for each farming system.

The second step of validating the model is to check if cropping areas and water use produced by model are consistent with their observed counterparts at the level of each individual governorate and then at DERAHA levels. Here some slight modifications are made on irrigation requirements to guarantee that the amount of water use produced by the model is close enough to that of the observed data. **Table 3.3** summarises the differences between observed data and the solution results at the governorate level for water use and the most important crops. To make the comparison easier, we assemble crops that occupy small areas in two groups. The group of intercalary crops, which include maize, sesame, watermelon, soybean, eggplant and tomato; they are all summer crops that are grown in the short season after wheat harvest in the same land plot , so they are grown in the period July-October. The group of other winter crops, on the other hand, includes all other crops which are: barley, peanut, lentil, chickpea, cumin, and spring potato, which are all winter crops that are grown usually in the period January-June.

Table 3.3 shows that differences in water use and cropping patterns are very small and they can be neglected given the classification adopted above. Although such classification may hide differences in terms of single crops that might be relatively large; however, this is not important when the areas of these crops singularly are very small as in our case. The total area of the group of other winter crops accounts only to about 3%, 2%, and 4% of the total cropped area in HAG, RAG, and DEG respectively. On the other hand, the area of the group of intercalary crops in HAG and RAG accounts to less than 1% and 7% of the total cropped area respectively.

DEG is the only governorate where the group of intercalary crops accounts a high share of the cropped area (22%). Maize accounts for the major part of this group (about 50%), while the other crops occupy all very small areas and most of them have not been considered in our model due to their minor importance such as haricot beans, garlic, cucumber, pepper, squash, etc. The magnitude of these crops is grown by farmers for purposes of home consumption. Tomato and eggplant, on the other hand, are two intercalary crops included in our model, but they do not appear in the solution's cropping mix, reflecting their low commercial value due to the low yields confirming that they are also grown for home consumption. The model solution gives an area (not shown in Table 3.2) for maize in the optimal solution to be double of the observed one, but this is due to the fact that so many crops are not included in the model due to their importance as clarified above. Therefore, since maize is the most profitable intercalary crops in DEG, it occupies the area of these crops in the solution.

The lowest part of **Table 3.3** represents the ranges of values that the absolute risk aversion coefficients take in the three governorates. According to the Expected Utility Theory, the value of an absolute risk aversion coefficient increases as risk aversion increases. In addition, the Theory predicts that risk aversion decreases as wealth increases. Here we test for this by calculating the coefficient of correlation between the values of risk aversion coefficient and the farm size which is considered to be an indicator of wealth. The corresponding coefficient of correlation for all DERAHA zone is equal -60% as shown in the table, which already illustrates a negative and high correlation between the two parameters along with the prediction of the Expected Utility Theory. However, the findings of the study survey, enhanced by the findings of other studies (Wattenbach 2006) emphasises the high importance of off-farm and non-agricultural income sources for farmers of DEG where average farm size is relatively very small. Calculating the coefficient of correlation after excluding the values associated with the DEG farm types gives the value of -80%, which illustrates a very high correlation. In DEG instead, farm holding size cannot be used an indicator of wellbeing since it generates only about 35-40% of the total households' income (Hamza 2004). This may explain the relatively low values of risk aversion coefficient found for farming systems of this governorate as illustrated in **Table 3.3**.

Chapter 4. Foreseen impact of policy change

This chapter is devoted to the discussion of some policy simulations and scenarios and their impacts on average income level, income stability, total and hired employment, and changes in cropping patterns and water use at the governorate level. In addition, returns to factors of production will be used to indicate the impacts on efficiency of resource utilisation.

Due to very large number of farming systems in our model, which amounts to 69, the discussion will be kept at the governorate level. Therefore, we will use the sum of GMs and CEs to indicate changes in income level and income stability at the governorate level. For total and hired agricultural labour use, it makes more sense to discuss them at the governorate level, which applies also to changes in cropping patterns and water use. However, due to the importance of water problem in AKB, we will mostly demonstrate the impact of any simulated policy on water deficit in this basin. The same cannot be done for Euphrates basin since a significant part of it is located in the governorate of Aleppo, which is not covered in this study, while the almost the entire area of AKB is located in HAG. Although some area of AKB is located in DEG, we neglect this part in the analysis for simplicity since we lack information on the location of farming systems at the basin level. Therefore, we will consider AKB to be identical to HAG.

Returns to factors of production are frequently used to indicate the efficiency of resource utilisation. We calculate them to demonstrate changes of resource use efficiency for the most important factors of production in DERAHA, namely land, labour and water.

The first and most relevant scenario is the measurement of the possible impact of the policy reforms that took place after the reference year of the study (2005), which is demonstrated and discussed in the following section in comparison with the baseline results that reflect the situation in 2005. The other scenarios are then performed on the new baseline, which reflects the situation in 2009 after the policy reforms and will be called below the *reform baseline*.

4.1. Impact of the recent policy reforms

This section is devoted to demonstrate and discuss the impact of the recent policy reforms on the performance of the agricultural sector of DERAHA; therefore, it is important to first describe these reforms.

4.1.1. The recent policy reform

Starting from 2005, the GOS undertook a series of reforms regarding many aspects of the agricultural policy, namely credit policy, pricing policy of inputs and outputs as well as the subsidy system of certain crops.

Concerning credit policy, the reform had an effect on all of its elements: interest rates, credit terms and the range of eligible activities. For a long time, the ACB used to offer credit only for pure agricultural activities, but now it can provide credit for various development projects (agricultural, industrial and constructional), on the condition that they will serve the process of rural development through employment creation and strengthening the linkages among the various economic sectors in the rural areas. It is believed according to this viewpoint that strengthening such linkages whether they are of production or consumption types would enhance the flows of labour and capital from the agricultural sector to the other sectors (or vice versa), which in turn, is expected to assist in achieving a comprehensive development in the Syrian countryside. However, changes in the interest rates for short-term credit form the only relevant reform to our analytical model. **Table 4.1** compares the old with the new types of loans offered by the ACB with their corresponding interest rates with respect to agricultural activities. Only short-term loans are relevant in our case as they are to fund the variable inputs and agricultural operations.

Table 4. 1. Interest rates adopted by the ACB according to loan term and activity

Term	sector	Old interest rate	New interest rate
Short term	Public and collectively cooperative	4%	6%
	Cooperative on behalf of members	4%	7%
	Private and co-joint sector	6%	8%
Medium term	Public and collectively cooperative	6%	7%
	Cooperative on behalf of members	6%	8%
	Private and co-joint sector	7.5%	9%
Long term	Public and collectively cooperative	7%	8%
	Cooperative on behalf of members	7%	9%
	Private and co-joint sector	8%	10%
Interest rate for the delay in repayment		10%	12%

Source: Source: Parthasarathy (2001), http://www.agrobank.org

The choice of a new interest rate is somehow problematic since the official one differs according to the type of borrowers (**Table 4.1**). However, since we lack data at the farming system level, we assume a unique interest rate for all farmers, based on a weighted average of the three ones reported in **Table 4.1** after adding the 1% commission for the benefit of the ACB (refer to **section 3.4.5**). The new selected interest rate is equal to 8.5%.

Diesel, in Syria, had been highly supported until recently. For example, the consumer price of diesel in the neighbouring countries (Lebanon e.g.) used to fluctuate between 25 and 35 SP/litre according to the world price movements, while it was fixed in Syria at 7.40 SP/litre. This old price policy of diesel had two reasons. The first one aimed at supporting consumers as Syrian people use mainly diesel for heating in winter. The second aimed to stimulate economic development, agricultural and industrial, through providing cheap source of energy. However, this policy had caused a drain on the public budget after the increase in international prices causing the smuggling of huge quantities of diesel from Syria (where prices were very low) to the neighbouring countries especially Lebanon (where prices were in line with the international ones). This problem recently urged the GOS to revise the policy and amend it by increasing the price of diesel from 7.4 SP/litre to 25 SP/litre in 2008 before being reduced to 20 SP/litre in 2009.

Following the increase of diesel price, the GOS undertook a series of actions aiming at compensating the farmers for the increased costs of production resulting mainly from the increase of diesel price. Consequently, the prices of strategic crops were raised as follows.

- Wheat (durum): 20 SP/kg,
- Wheat (soft): 19.5 SP/kg,
- Barley: 16 SP/kg
- Cotton: 41 SP/kg
- Sugar beet: 3.75 SP/kg
- Lentils: 23 SP/kg (no change occurred)
- Chickpeas: 25 SP/kg (no change occurred)

In addition, a subsidy of 30 thousand SP/ha is given to producers of cotton irrigated from private wells. In addition, the new reforms joined maize to the group of strategic crops and determined for it a floor price equal to 16 SP/kg.

Furthermore, prices of chemical fertilisers have been recently subject to noticeable increase as a result of one further step towards the liberalisation of the agricultural sector in Syria. The new prices became as follows:

- Nitrogen fertiliser: 18 SP/kg
- Phosphate fertiliser: 23.9 SP/kg
- Potash fertiliser: 57.2 SP/kg

4.1.2. The 2005 baseline results versus reform baseline results

In order to estimate the impact of the aforementioned policy reforms, we have to run the mathematical programming model after adjusting the relevant policy parameters to be in line with the reforms. As explained in **section 3.2**, official prices need to be adjusted to reflect the effective prices that farmers receive, this implies adding the transaction costs to prices of inputs and subtracting them from the prices of outputs.

Having selected new effective prices, we deflated them using the wholesale price index calculated by the Syrian Central Bureau of Statistics (CBS), taking 2005 as a base year since it is the reference year of our data.

The new prices became:

- Wheat: 14.77 SP/kg for durum and 19.5 SP/kg for soft
- Barley: 11.74 SP/kg
- Cotton: 28.00 SP/kg (the decisions do not state and price differentiation according to delivery dates as before)
- Sugar beet: 2.54 SP/kg
- Lentils: 23 SP/kg (no change occurred)
- Chickpeas: 25 SP/kg (no change occurred)
- Maize: 12.12 SP/kg
- Nitrogen fertiliser: 13.64 SP/kg
- Phosphate fertiliser: 18.11 SP/kg
- Potash fertiliser: 43.33 SP/kg
- Subsidy for cotton irrigated from private wells: 23,000 SP/ha

The objective function of the our model needs to be adjusted as well to consider the subsidy given for cotton irrigated from private wells. The new objective function is:

$$R = \sum_j P_j * Ep_j + \sum_w \sum_i X_{cotton,i,w} * Pw * Cots \qquad [4.1]$$

Where:

$Cots$: is the subsidy that is given to cotton irrigated from private wells (SP/ha).

Pw: is a dummy variable that takes the value of one if the farm is irrigated from well, zero otherwise.

Table 4.2 compares the 2005 baseline results with the reform baseline results for cropping patterns and water use at the governorate level. Note that we separated here maize from other intercalary crops in order to see the impact of stabilising its price in the recent reform.

Noticeable changes are observed for areas of maize and intercalary crops. Maize area increases in all governorates, while intercalary crops' area decreases in HAG and RAG but it increases significantly in DEG. Stabilising maize price has a positive impact on its cultivated area as expected, but the importance of this impact differs according to the pre-reform situation. It is noticeable that, in DEG, the small increase in the area of maize is coupled with a large increase in the area of other intercalary crops, reflecting that the increased costs (due to increased in input prices) significantly offset the increased revenue from maize due to stabilising and supporting its price. Changes in areas of wheat, cotton, sugar beet and other winter crops are not that large. Noticeable only is the decrease of cotton area in DEG which is maybe due to the same reason proposed for the small increase in maize, this is supported by the fact that cotton is very demanding in terms of variable inputs especially diesel whose price was subject to a big increase.

Table 4. 2. the 2005 baseline results versus reform results for cropping mixes and water use

	2005 baseline results	Reform baseline results	% change
Water use (million CM)			
In HAG	3595	3575	-0,56
In RAG	3146	3391	7.79
In DEG	2369	2473	4.39
Wheat area (ha)			
In HAG	341408	341933	0.15
In RAG	135729	134983	-0.55
In DEG	106822	109578	2.58
Cotton area (ha)			
In HAG	87447	87447	0.00
In RAG	60147	60148	0.00
In DEG	25106	22906	-8.76
Sugar beet area (ha)			
In RAG	4958	4958	0.00
In DEG	4132	3701	-10.43
Maize area (ha)			
In HAG	0	398	Undefined
In RAG	12067	30092	149.37
In DEG	36213	39498	9.07
Intercalary crops area (ha)			
In HAG	3441	2871	-16.56
In RAG	3597	1963	-45.43
In DEG	5234	13987	167.23
Other winter crops area (ha)			
In HAG	13396	12872	-3.91
In RAG	3848	4594	19.39
In DEG	6515	6189	-5.00
Total cropped area (ha)			
In HAG	445693	445521	-0.04
In RAG	220347	236738	7.44
In DEG	184024	195859	6.43

Source: study results

Concerning water use, noticeable is the increase of water use in RAG and DEG reflecting the overall increase of the cropping area of these two governorates, while the it remains somehow stable in HAG (**Table 4.2**).

Concerning water use, availability and balance at AKB level, **Table 4.3** shows that although water balance improves slightly after the reforms, a large deficit is still witnessed and water saved accounts only to 20 million CM less than 1% of the water used.

Table 4. 3. Foreseen impact of policy reforms on water use and balance in AKB

Water availability (million CM)	2388
Water use before reform (million CM)	3595
Water use after reform (million CM)	3575
Water balance before reform (million CM)	-1207
Water balance after reform (million CM)	-1187
Water saved (million CM)	20

Source: study results, GCASR (2006)

The impact of the policy reforms on income and employment is generally positive although obvious differences exist among governorates. Impact on total and hired employment is negligible in HAG which is consistent with the minor changes in cropping patterns as mentioned above. The same elucidation applies to changes in average income and income stability although the latter witnesses improvement while the former witnesses reduction (**Table 4.4**).

Table 4.4 also reveals improvement in employment, average income and income stability in both RAG and DEG. The increase in hired employment is conspicuous in DEG (30%) which is mainly due to low use of hired labour in the 2005 baseline results since farms in DEG are generally small and are characterised by high level of family labour use. However, the overall improvements in income and employment variables is mainly due to the expansion of intercalary crops cultivation, namely maize, since they require a proportionately high labour requirements added to the impact of stabilising the price of maize which is evidently behind the increase in income level and stability.

Table 4. 4. Foreseen impact of policy reform on employment and income in DERAHA

Governorate	HAG	RAG	DEG	total DERAHA
Total agricultural employment (thousand hour)				
2005 baseline results	145489.88	90092.58	56316.13	291898.59
reform baseline results	144765.20	95787.41	58644.86	299197.47
% change	-0.50%	+6.32%	+4.14%	+2.50%
Hired agricultural employment (thousand hour)				
2005 baseline results	36696.74	31614.67	50.86	68362.27
reform baseline results	36428.96	33456.17	66.28	69951.41
% change	-0.73%	+5.82%	+30.32%	+2.32%
Sum of Gross Margins (million SP)				
2005 baseline results	12975.57	8793.99	5993.6	27763.16
reform baseline results	13402.42	9780.33	6915.52	30098.26
% change	+3.29%	+11.22%	+15.38%	+8.41%
Coefficient of variation of Gross margins at farms' level				
2005 baseline results	0.53	0.41	0.18	0.67
reform baseline results	0.55	0.39	0.20	0.67
% change	+2.85%	-4.02%	+15.26%	+0.20%
Sum of Certainty Equivalents (million SP)				
2005 baseline results	12794.99	8590.02	5509.12	26894.13
reform baseline results	13260.61	9709.99	6558.25	29528.85
% change	+3.64%	+13.04%	+19.04%	+9.80%
Coefficient of variation of Certainty Equivalents at farms' level				
2005 baseline results	0.54	0.42	0.18	0.68
reform baseline results	0.55	0.40	0.20	0.68
% change	+2.72%	-5.10%	+9.02%	-0.39%

Source: study results

Table 4.4 also reports the coefficient of variation of average income and income stability among individual farming typologies. This coefficient is used as a indicator for income distribution among different farming systems at the governorate level as well as at DERAHA level. The results show an a slight increase in the variation of average income and income stability in the entire region; however, the changes in the value of this coefficient are different from governorate to the other; while they are positive in HAG and DEG, they are negative in RAG, illustrating an fall in income equality in the former case but an increase in the latter. Therefore, although the new policy reforms promote average income and income stability in all governorates, they promote income equality only in RAG.

Returns to factors of production are usually used to as indicators on the efficiency of resource utilisation. **Table 4.5** illustrates the impact of the recent policy changes on returns to land, labour and water. In line with improvements in income level and stability demonstrated above, returns to the three resources witness some improvements. Not surprisingly, DEG, which witnesses the highest improvement in income level and in income stability, observes also the highest improvement in returns to factors of production (about 8-10%) followed by RAG which has a similar situation although the percentage changes for all variables are lower than those of DEG. Here it is interesting to highlight the fact that improvements in income level and stability in these two governorates are due to both increased profitability of some crops and the increased cropped area (**Tables 4.3** and **4.4**). HAG also observes an improvement in returns to factors of production although it is the only governorate in which no improvement is noticed in the cropped area, which means that this improvement is due only to the increased profitability of some crops due to the recent policy reforms.

Table 4. 5. Impact of policy reforms on returns to land, labour and water

governorate	HAG	RAG	DEG	DERAHA
GM per ha (SP/ha)				
2005 baseline results	29113.24	39909.81	32569.59	32660.08
reform baseline results	30082.57	41312.93	35308.61	34275.87
% change	3.33%	3.52%	8.41%	4.95%
GM per unit of family labour (SP/hour)				
2005 baseline results	119.27	150.38	106.52	124.2
reform baseline results	123.71	156.91	118.06	131.29
% change	3.72%	4.34%	10.83%	5.71%
GM per unit of total labour (SP/hour)				
2005 baseline results	89.19	97.61	106.43	95.11
reform baseline results	92.58	102.1	117.92	100.6
% change	3.80%	4.60%	10.80%	5.77%
GM per unit of water use (SP/CM)				
2005 baseline results	3.61	2.8	2.53	3.05
reform baseline results	3.75	2.88	2.80	3.19
% change	3.88%	2.86%	10.67%	4.59%

Source: study results

4.2. Simulations of new alternative policies

4.2.1. Impact of modernising the irrigation system

The awareness in the importance of modern irrigation to ration the use of water has recently risen in Syria, especially that the agricultural sector consumes about 90% of the total water use in the Country, while irrigated areas using modern irrigation techniques do not account to more than 20%. This percentage is much less in DERAHA and it was 7% in 2007. This issue has become more relevant after the subsequent waves of drought that hit the Country.

As a response to that the GOS declared in 2005 the foundation of the Department of the NPCMI, which was later coupled with the foundation of a national Fund for the conversion to modern irrigation, linked directly to the MAAR, aiming to convert all irrigated areas of the Country to modern irrigation techniques. The fund works with favourable credit terms since loans are without interest and the repayment period lasts for ten years. In addition, the fund will contribute up to 20-35% of the costs as a subsidy. Later on, the GOS declared that conversion to modern irrigation is obligatory and all farmers will have access to the credit, since even personal collateral became accepted.

The loans are combined with extension and training programs to assist farmers on technical aspects on the use of modern irrigation techniques. Potential beneficiaries will be classified in groups so that priorities can be considered, which will be first given to small and poor farmers. Furthermore, priorities will be given to areas more technically suitable to modern irrigation, or to areas where the dominant cropping patterns are more appropriate for the adoption of modern irrigation on the technical, practical and economic aspects. Priorities are also given to areas where water problem is critical (e.g. AKB).

This simulation is performed in two separate scenarios: first, we will assess the impact of conversion to modern irrigation on all the model variables; second, we will assess the impact of increasing irrigation efficiency after adopting modern irrigation techniques.

4.2.1.1. Impact of adopting modern irrigation techniques

This scenario aims to assess the impacts of converting all farms to modern irrigation which implies that farmers have to install two kinds of modern irrigation nets: drip and sprinkler. This is based on the fact that the suitability of the two techniques differs according to different crops. For example, while cotton can be irrigated with both techniques, it can be argued that it is better to irrigated with drip irrigation since water saving and cotton yields are higher with drip irrigation than with sprinkler. On the other hand, some crops, such as wheat and barley, cannot be irrigated by drip irrigation nets.

The model takes into account such technical disparities and constraints in which it differentiates crops' yields according to irrigation techniques, and when a crop is not irrigable by a certain technique its yield then is assumed to be zero. Modern irrigation techniques are modelled by dummy variables, which take the value of one if the relevant technique exists in the corresponding farm type, zero otherwise. This implies that when a farm has the values of the two dummies equal to zero, the only available irrigation techniques are flood and rainfed (without irrigation). Therefore, the scenario is performed by converting all the values of the dummies to one. **Table 4.6** demonstrates the potential impact of the conversion on water use and cropping patterns in DERAHA.

Table 4. 6. Impact of conversion to modern irrigation on water use and cropping patterns

	reform baseline	Conversion to modern irrigation	% change
Water use (million CM)			
In HAG	3575	3213	-10.13
In RAG	3391	3063	-9.66
In DEG	2473	2301	-6.97
Wheat area (ha)			
In HAG	341933	342116	+0.05
In RAG	134983	136154	+0.87
In DEG	109578	108923	-0.60
Cotton area (ha)			
In HAG	87447	87447	+0.00
In RAG	60148	60148	+0.00
In DEG	22906	25106	+9.60
Sugar beet area (ha)			
In RAG	4958	4687	-5.46
In DEG	3701	3992	+7.87
Maize area (ha)			
In HAG	398	6776	+1602.53
In RAG	30092	42584	+41.51
In DEG	39498	46986	+18.96
Intercalary crops area (ha)			
In HAG	2871	2973	+3.56
In RAG	1963	2220	+13.11
In DEG	13987	13967	-0.14
Other winter crop area (ha)			
In HAG	12872	12689	-1.42
In RAG	4594	4408	-4.05
In DEG	6189	6104	-1.37
Total cropping area (ha)			
In HAG	445521	452001	+1.45
In RAG	236738	251798	+6.36
In DEG	195859	205079	+4.71

Source: study results

A part from the increases in the area of maize in all DERAHA, especially in HAG, and decreases in areas of the group of other winter crops in RAG as well as increases of Intercalary crops area in RAG, no important changes in cropping patterns take place as a result of conversion to modern irrigation. Obviously, the increases of yields are behind the increases in the area of some crops, that is the area of maize is doubled several times in HAG. The quantity of water saved is also small due to two reasons: the first is technical in the sense that the efficiency of modern irrigation technique is low due to know-how constraints. Several studies highlighted that farmers lack the required knowledge and skills that enable them to use the modern technology efficiently (NAPC 2005a, Somi 2002, Varela-Ortega and Sagardoy 2001). In addition, our model assumes that sprinkler and drip techniques save 10% and 20% respectively compared to the flood traditional one, which may lead to expect that water saved should be 10% at least when both techniques are adopted. However, the percentage of water saved relative to total use reaches 10% only in HAG, which implies that a portion of the water saved by the adoption of modern irrigation is being used to expand the area of some crops that was not possible before since water constraint was binding.

Table 4. 7. Impact of conversion to modern irrigation on water use and balance in AKB

Water availability (million CM)	2388
Water use of reform baseline (million CM)	3575
Water use after conversion to modern irrigation (million CM)	3213
Water balance after reform (million CM)	-1187
Water balance after conversion to modern irrigation (million CM)	-825
Water saved after conversion to modern irrigation (million CM)	362

Source: study results

At the level of AKB, the amount of water saved is noticeable (more than 10% million CM); however, there remains a significant deficit of more than 800 million CM (**Table 4.7**). This duplicates the results of several past studies, stating that given the current efficiency of modern irrigation techniques, the latter cannot solve the problem of water deficit in AKB, and therefore, a change in the cropping patterns may be inevitable if water deficit is to be restored. However, other sources assume that there is a large space to improve the efficiency of modern irrigation through a set of possible instruments. The impact of that on the water use and balance is going to be traced in the following section.

Table 4. 8. Impact of conversion to modern irrigation on employment and income

Governorate	HAG	RAG	DEG	total DERAHA
Total agricultural employment (thousand hour)				
Reform baseline	144765	95787	58645	299197
Conversion to modern irrigation	147017	99202	63300	309519
% change	+1.56%	+3.57%	+7.94%	+3.45%
Hired agricultural employment (thousand hour)				
Reform baseline	36429	33456	66	69951
Conversion to modern irrigation	37129	46864	73	84066
% change	+1.92%	+40.08%	+10.23%	+20.18%
Sum of Gross Margins (million SP)				
Reform baseline	13402	9780	6916	30098
Conversion to modern irrigation	17650	12320	8807	38778
% change	+31.70%	+25.98%	+27.35%	+28.84%
Coefficient of variation of Gross margins at farms' level				
Reform baseline	0.55	0.39	0.20	0.67
Conversion to modern irrigation	0.50	0.38	0.20	0.62
% change	-8.30%	-1.97%	-1.85%	-8.23%
Sum of Certainty Equivalents (million SP)				
Reform baseline	13261.0	9710.0	6558.0	29529.0
Conversion to modern irrigation	17481.6	12238.0	8354.4	38074.0
% change	+31.83%	+26.04%	+27.39%	+28.94%
Coefficient of variation of Certainty Equivalents at farms' level				
Reform baseline	0.55	0.40	0.20	0.68
Conversion to modern irrigation	0.51	0.39	0.19	0.68
% change	-8.40%	-2.38%	-2.58%	-8.32%

Source: study results

Nevertheless, the impact of conversion to modern irrigation is positive generally on agricultural employment and incomes. This is shown clearly in **Table 4.8** where the increases in all variables are obvious. Very distinct is the relatively higher increase in agricultural hired employment in RAG, which is due to a lesser family labour availability in that governorate relative to the other ones. However, the general increases in employment in all DERAHA are likely to be caused by increased yields resulting from adopting the modern techniques, while general increased incomes are caused also by reduced pumping costs.

Table 4. 9. **Impact of conversion to modern irrigation on returns to land, labour and water**

Governorate	HAG	RAG	DEG	total DERAHA
GM per ha (SP/ha)				
Reform baseline	30083	41313	35309	34276
Conversion to modern irrigation	39049	49383	42797	42741
% change	+29.80%	+19.53%	+21.21%	+24.70%
GM per unit of family labour (SP/hour)				
Reform baseline	124	157	118	131
Conversion to modern irrigation	161	235	139	172
% change	+29.53%	+49.94%	+18.05%	+31.30%
GM per unit of total labour (SP/hour)				
Reform baseline	93	102	118	101
Conversion to modern irrigation	120	124	139	125
% change	+29.09%	+21.76%	+17.92%	+24.04%
GM per unit of water use (SP/CM)				
Reform baseline	3.75	2.88	2.80	3.19
Conversion to modern irrigation	5.49	4.02	3.83	4.52
% change	+46.40%	+39.58%	+36.79%	+41.69%

Source: study results

Table 4.8 also reports the coefficient of variation of average income and income stability among individual farming typologies. The results show that this scenario generally promotes income equality since the coefficient of variation witnesses a fall in the three governorates although the magnitude of this fall differs from one governorate to the other. It is interesting to note that this fall is considerable in HAG where the coefficient of variation has a noticeably higher value in the reform baseline, but the equality impact of the scenario is higher there.

Concerning the impact on returns to farms' resources, the model predicts significant improvements. Increased returns to land are caused by increased average income and reduced costs (due to reduced pumping costs of irrigation) per hectare. Returns to water is caused by increased average incomes per hectare and reduced irrigation requirements by crops. Returns to family labour are very high in RAG, since family labour availability is relatively low in that governorate, given that increased returns to labour in general are caused by the fact that incomes are increased more proportionately than labour requirements (**Table 4.9**).

4.2.2.2. Impact of improving irrigation efficiency

Although significant improvements are observed in terms of incomes, employment and returns to factors of production due to the adoption of modern irrigation techniques, the benefit in terms of water saving is very small due to the low current efficiency. This indicates that there exists a room for improving irrigation efficiency through improving the know-how of farmers. Previous studies demonstrate the existence of technical, environmental, and educational constraints that limit the efficiency of modern irrigation. These constraints relate to different soil quality, different types and qualities of irrigation networks, and lack of know-how from the side of farmers on how to use modern irrigation techniques effectively.

In this sub-scenario, we will assume a gradual increase in the efficiency of modern irrigation that would be the consequence of releasing one or more of the constraints highlighted above. The scenario is performed by the use of an *efficiency parameter* that takes the value of zero at the status quo. This parameter is introduced into equations [3.11] and [3.29] as well as into inequality [3.18] that are all transformed to the following formulae:

$$Ic = \sum_c \sum_i \sum_w X_{c,i,w} * Dq_{c,i,w} * Dp * (1 - ep) \qquad [4.2]$$

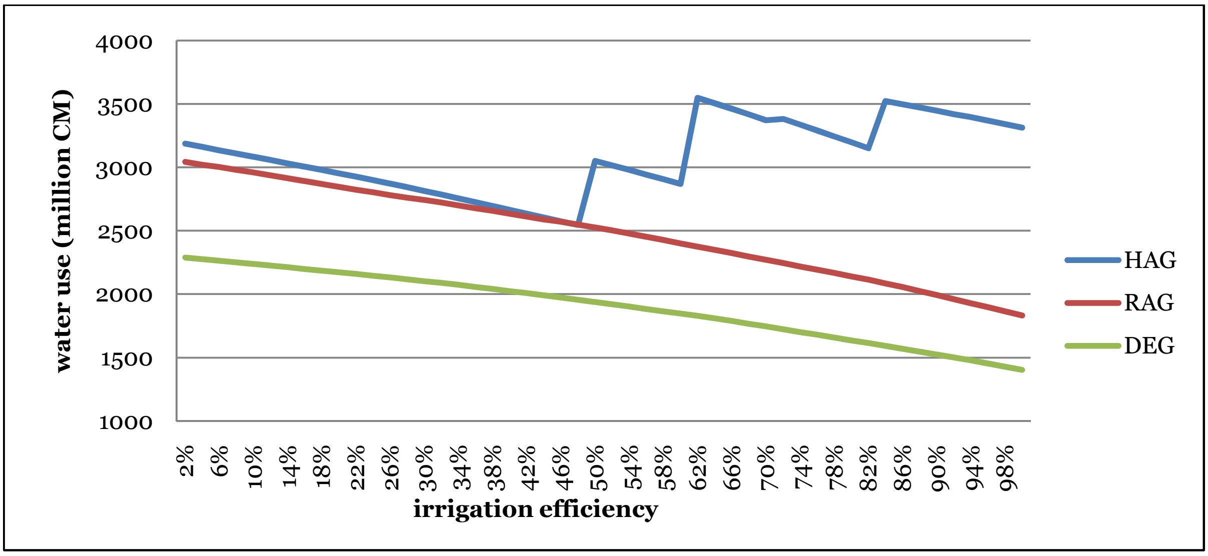
$$\sum_c \sum_i \sum_w X_{c,i,w} * Watr_{c,i,t} * (1 - ep) \leq Wat_t \qquad [4.3]$$

$$Wuse = \sum_t \sum_c \sum_i \sum_w X_{c,i,w} Watr_{c,i,t} * (1 - ep) \qquad [4.4]$$

Where ep is the irrigation efficiency parameter, while all other terms are defined in **section 3.2**. Increasing irrigation efficiency is performed by a gradual growth in the value of the efficiency parameter, assuming a linear relationship between water consumption and pumping costs as reflected in the equations [4.2] and [4.4]. Therefore, when the efficiency parameter has the value of zero, it corresponds to the current irrigation efficiency, while when it takes the value of 0.5, it corresponds to an increase in irrigation efficiency equal to 100%, implying that irrigation requirements of all crops are reduced to half.

Figure 4.1 traces the impact of improving irrigation efficiency on water use in the three governorates of DERAHA. All governorates witness a gradual decrease in water use at the beginning. At higher levels of efficiency, however, while water use in RAG and DEG continues to go down, HAG witnesses an increased water use that persists even when irrigation efficiency reaches 100% (when the efficiency parameter has the value of 0.5). It is interesting to notice that the rise of water use is materialised though discrete jumps.

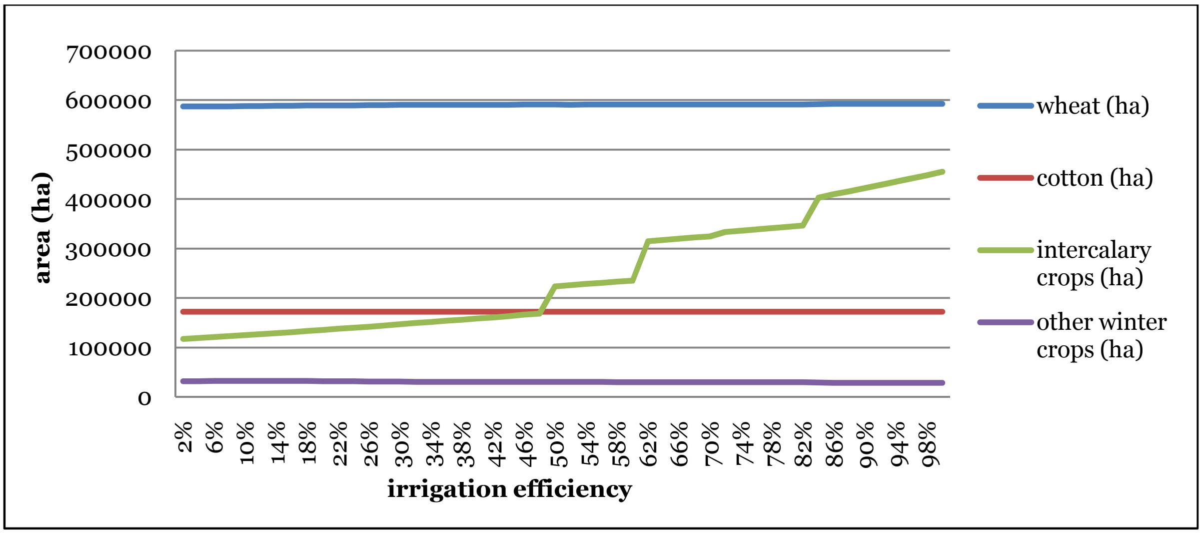
Figure 04.1. Impact of improving modern irrigation efficiency on water use



Source: study results

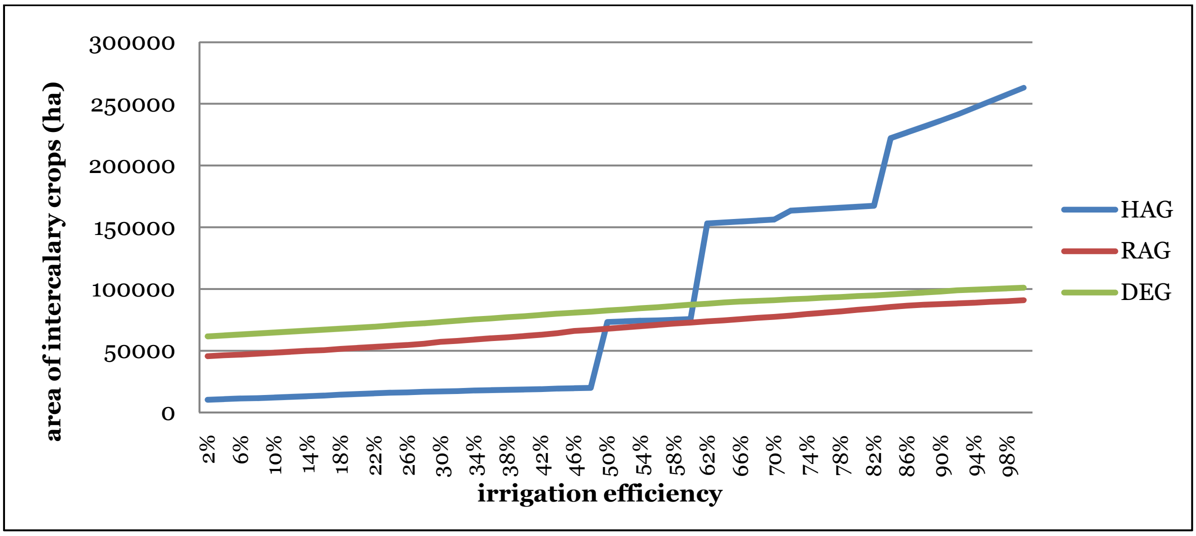
Figure 4.2, which illustrates the impact of improving irrigation efficiency on cropping patterns of all DERAHA, furnishes some hints about the reasons behind the seemingly strange behaviour in HAG. It demonstrates that areas of all crops remain constant except that of intercalary crops which witnesses significant increases similar in their forms to those of water use in **Figure 4.1**. **Figure 4.3** completes the image by showing that area of intercalary crops grows only in HAG as irrigation efficiency increases. This phenomenon is explained by the fact that in HAG water saved by increasing irrigation efficiency gets used to expand the cultivation of some intercalary crops, namely maize. These crops are not cultivated in large area under low levels of irrigation efficiency mainly due to irrigation water constraint, but also due to high pumping costs that make such crops much less profitable in HAG then. As irrigation efficiency increases, the available water in each farm becomes sufficient to irrigate more extra areas and the pumping costs of a unit of water is decreased.

Figure 04.2. Impact of improving modern irrigation efficiency on cropping patterns



Source: study results

Figure 4.3. Impact of improving irrigation efficiency on area of intercalary crops

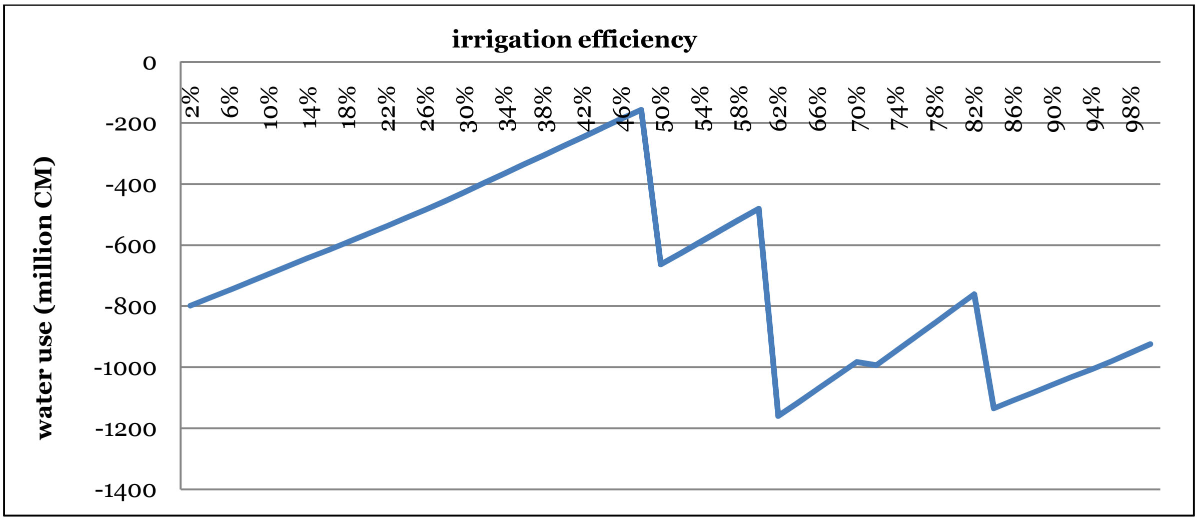


Source: study results

All of the above has implication for the most efficient way to solve the water problem in AKB. **Figure 4.4** shows how water deficit approaches zero at efficiency level of about 50%, but then it goes up again in a fluctuating way that reflects rapid increases in the area of intercalary crops at certain levels of irrigation efficiency. This points out that modernising the irrigation system may not suffice to restore water balance in Al-Khabour, a very important point that we have to come back to in the next chapter.

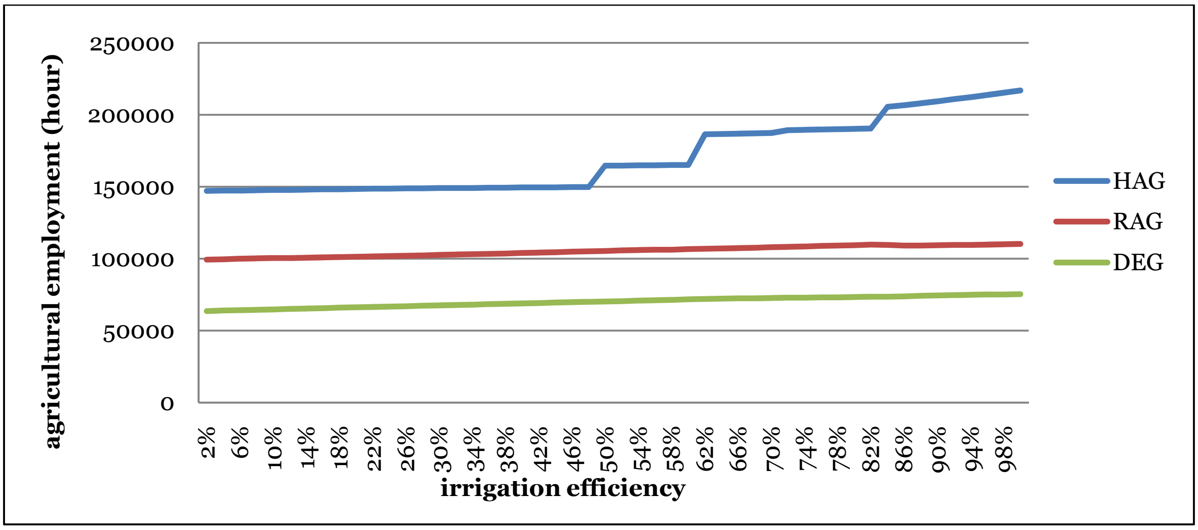
The impact of increasing irrigation efficiency on agricultural employment and income is shown in **Figures 4.5** and **4.6** respectively. Agricultural employment increases in line with the expansion of intercalary crops' cultivation; therefore, while it increases at a constant rate in RAG and DEG it witnesses some jumps in HAG. Increases of agricultural incomes on the other hand occur at a constant rate as shown in **Figure 4.6**.

Figure 04.4. Impact of improving irrigation efficiency on water balance in AKB



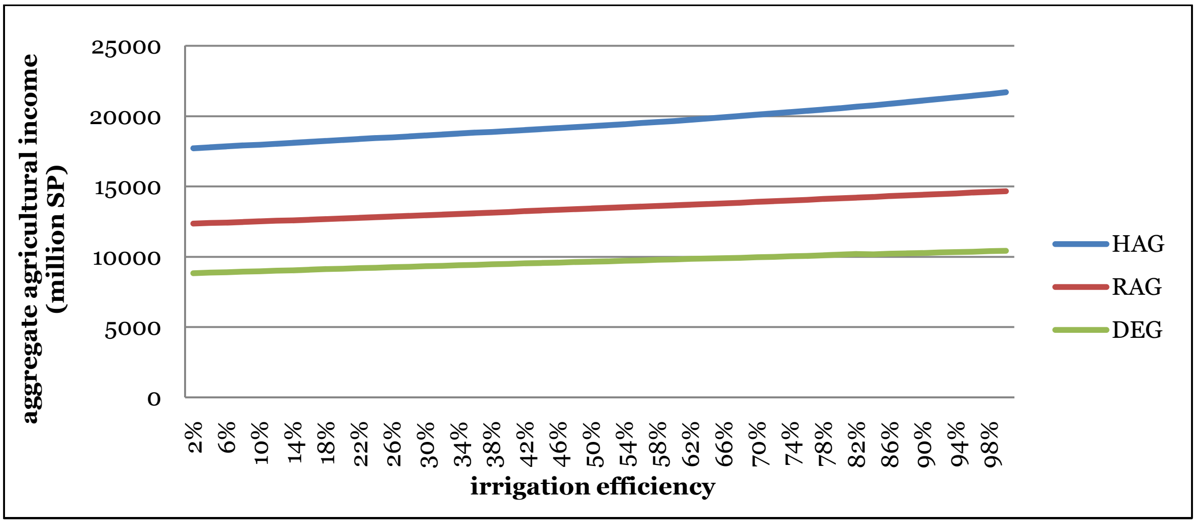
Source: study results

Figure 04.05. Impact of improving irrigation efficiency on agricultural employment



Source: study results

Figure 04.6. Impact of improving irrigation efficiency on aggregate agricultural income



Source: study results

4.2.1. Impact of stabilising and increasing cumin price

This simulation aims at measuring the impact of stabilising and increasing the price of cumin, which is a crop that has not been important for the Syrian agriculture so far. However, it may be a promising crop for the future since it has a growing international market due to the expansion of its use in medical industries. Furthermore, cumin can help to save water since it has low irrigation requirements; in fact, it is mostly grown in Syria now as a rainfed crop in agro-climatic zones 1, 2 and sometimes 3. However, its yield experiences high degree of fluctuations especially in zones 2 and 3 due to rainfall fluctuations, and so it is assumed that some supplementary irrigation may help in increasing and stabilising its yields.

Our analytical model allows cumin to be cultivated with or without irrigation, and its yield differs according to that. When it is grown without irrigation its yield differs according to agro-climatic zones, while it has a stable yield once it is grown with irrigation. In the latter case, however, it has different irrigation requirements according to different agro-climatic zones. The simulation consists of two scenarios: in the first one we will measure the impact of stabilising cumin price, while in the second we will trace the impact of increasing the price after having stabilised it.

4.2.1.1. Impact of stabilising cumin price

The scenario is performed by assuming that the GOS guarantees a stable price for cumin, and this price is supposed to be the mean of the price series of cumin shown in **Table 3.1**. which is equal to 50.08 SP/kg. **Table 4.11** summarises the results of this scenario comparing them with the results of reform baseline. The table shows some interesting changes in water use and cropping patterns. First thing is that cumin appears in the cropping mixes of all governorates, its area in HAG is extremely large where it accounts about 30% of the total cropped area. Its area is also markedly large in RAG, and it counts to about 12% of the total cropped area. Coupled with this, HAG also witnesses a great increase in the area of intercalary crops and a sharp decrease in the area of wheat. The interpretation of these changes is that cumin with stable price has a certainty equivalent higher than that of wheat for many farming systems, knowing that they both compete for land as they are both winter crops and grown over the period from November to June.

Moreover, cumin irrigation requirements are much lower than those of wheat, which means that the former farming systems will have more irrigation water that can be used to produce a crop that does not compete with cumin for land which is maize in our case. The same analysis applies also to many farming systems in RAG which demonstrates a similar situation of HAG although the sharp decrease is more with the group of other winter crops. On the other hand, areas of cotton and sugar beet are almost unchanged, but the total cropped area experiences a very small change in the three governorates. Water use goes down in the three governorate though its reduction is only perceptible in HAG. This illustrates the importance of this scenario for water balance in AKB, as **Table 4.10** confirms a large amount of water saving equal to 375 million CM. However, water deficit is still high enough to doubt the sufficiency of this scenario to deal with water problem in AKB.

Table 4. 100. Impact of cumin price stabilisation on water use and balance in AKB

Water availability (million CM)	2388
Water use reform baseline (million CM)	3575
Water use after stabilising cumin price (million CM)	3200
Water balance reform baseline (million CM)	-1187
Water balance after stabilising cumin price (million CM)	-812
Water saved (million CM)	375

Source: study results

Table 4. 111. Impact of stabilising cumin price on water use and cropping patterns

	reform baseline results	Scenario results	% change
Water use (million CM)			
In HAG	3575	3200	-10.50
In RAG	3391	3260	-3.88
In DEG	2473	2467	-0.24
Wheat area (ha)			
In HAG	341933	208466	-39.03
In RAG	134983	106440	-21.15
In DEG	109578	109578	0.00
Cotton area (ha)			
In HAG	87447	87447	0.00
In RAG	60148	60145	0.00
In DEG	22906	22906	0.00
Sugar beet area (ha)			
In RAG	4958	4687	-5.45
In DEG	3701	3701	0.00
cumin area (ha)			
In HAG	0	133650	undefined
In RAG	0	30193	Undefined
In DEG	0	1297	Undefined
Intercalary crops area (ha)			
In HAG	3269	10117	209.48
In RAG	32055	35551	10.91
In DEG	53485	53485	0.00
Other winter crops area (ha)			
In HAG	12872	12689	-1.42
In RAG	4587	3218	-29.85
In DEG	6189	4683	-24.34
Total cropped area (ha)			
In HAG	445521	452369	1.54
In RAG	236738	240234	1.48
In DEG	195859	195650	-0.11

Source: study results

The impact of this scenario on income and agricultural employment follows the line of conclusions drawn above. In DEG, where no vital change occurred to the cropping patterns, income and employment remained almost unchanged. The only exception is that hired labour use decreases by 22%; however, this change is negligible knowing that hired labour is already very small in DEG. The highest increase in income level, income stability and agricultural employment is in HAG where all variables increases by about 15% with the exception of hired labour which increases by about 40%. This is explained by the fact that labour requirements of cumin are much higher than those of wheat due to the need for intensive labour during the harvest season. In RAG all variables improve, but at a lower rate than that of HAG. This scenario also promotes income equality since the coefficient of variation for income level and stability decreases especially in RAG and HAG where cumin area expands greatly (**Table 4.12**).

The analysis of the scenario's impact on resource use efficiency demonstrates some interesting results. **Table 4.13** shows that there is no observable change in DEG. However, in RAG, the returns to land and water go up, while those of labour go down whether counting for family or for total labour. In HAG, only total labour productivity goes down while all other variables go up. The increases in land and water productivities are easily understood as the stabilisation of cumin price promotes average income and certainty equivalents and cumin is less consuming of water. The decreases in labour productivity are due to the fact that cumin uses more labour than the main substituted crop (wheat). However, the improvement of family labour productivity in the case of HAG is mainly due to scarcity of family labour that makes many farming systems rely very much on hired labour.

Table 4. 12. Impact of stabilising cumin price on employment and income in DERAHA

Governorate	HAG	RAG	DEG	total DERAHA
Total agricultural employment (thousand hour)				
Reform baseline results	144765	95787	58645	299197
Scenario results	169560	101695	58645	329900
% change	17.13%	6.17%	0.00%	10.26%
Hired agricultural employment (thousand hour)				
Reform baseline results	36429	33456	66	69951
Scenario results	51632	35656	51	87340
% change	41.73%	6.58%	-22.31%	24.86%
Sum of Gross Margins (million SP)				
Reform baseline results	13402	9780	6916	30098
Scenario results	15319	9954	6917	32190
% change	14.30%	1.78%	0.02%	6.95%
Coefficient of variation of Gross margins at farms' level				
Reform baseline results	0.55	0.39	0.20	0.67
Scenario results	0.52	0.35	0.20	0.66
% change	-6.02%	-9.38%	-0.39	-1.55%
Sum of Certainty Equivalents (million SP)				
Reform baseline results	13261	9710	6558	29529
Scenario results	15187	9889	6565	31641
% change	14.53%	1.84%	0.10%	7.15%
Coefficient of variation of Certainty Equivalents at farms' level				
Reform baseline results	0.55	0.40	0.20	0.68
Scenario results	0.52	0.36	0.19	0.66
% change	-6.17%	-10.01%	-4.08%	-1.75%

Source: study results

Table 4. 13. Impact of cumin price stabilisation on returns to land, labour and water

governorate	HAG	RAG	DEG	DERAHA
GM per ha (SP/ha)				
reform baseline results	30083	41313	35309	34276
scenario results	33864	41435	35352	36239
% change	12.57%	0.30%	0.12%	5.73%
GM per unit of family labour (SP/hour)				
reform baseline results	124	157	118	131
scenario results	130	151	118	133
% change	5.00%	-3.94%	-0.02%	1.08%
GM per unit of total labour (SP/hour)				
reform baseline results	93	102	118	101
scenario results	90	98	118	98
% change	-2.41%	-4.13%	0.02%	-3.01%
GM per unit of water use (SP/CM)				
reform baseline results	3.75	2.88	2.80	3.19
scenario results	4.79	3.05	2.80	3.61
% change	27.73%	5.90%	0.00%	13.17%

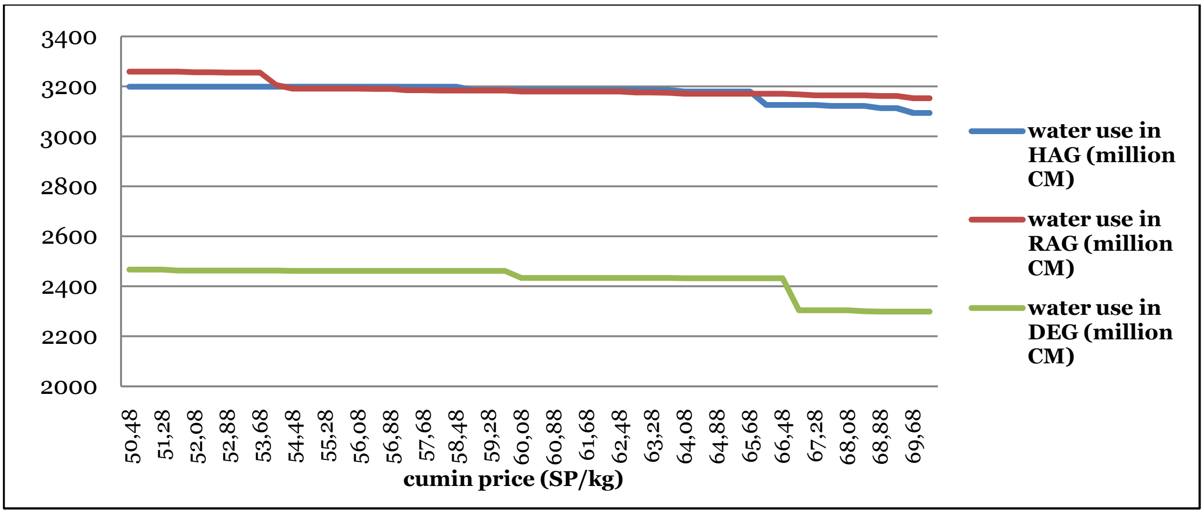
Source: study results

4.2.1.2. Impact of increasing cumin price

Figure 4.7 traces the impact of increasing cumin price on water use in DERAHA. It is noticeable the decrease of water use in the three governorates as cumin price goes up. In HAG, the rate of water use decline is slow for lower cumin price, but it accelerates when price reaches 65 SP (about 85 SP in current prices of 2009). In RAG instead, water use declines fast at low levels of cumin price to slow down immediately when cumin price reaches 54 SP (about 70 SP in current prices of 2009). The situation in DEG is more similar to that of HAG although it seems that in at high levels of cumin price, the reduction in water use is more significant in DEG. This is because cumin becomes highly profitable when it reaches 65 SP in DEG (about 88 SP in 2009 current prices) and it starts to replace wheat.

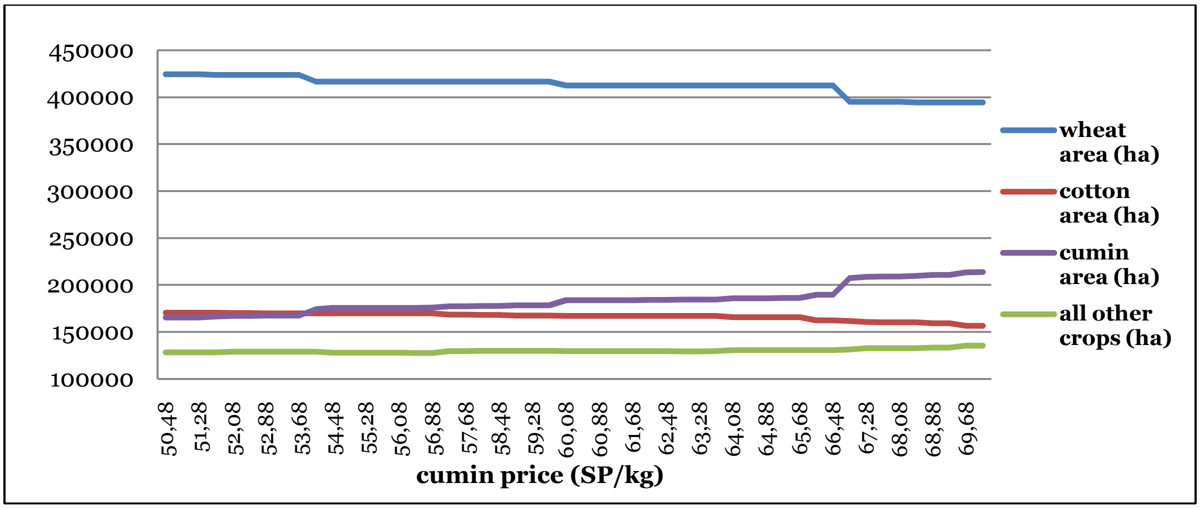
Figure 4.8, on the other hand, demonstrates the impact on cropping patterns in all DERAHA region. At the aggregate level of the region, areas of all other crops tend to decrease while cumin area increases steadily. It is obvious the reduction in wheat area at the price of 65 SP when a significant reduction in water use occurs in DEG, which is coupled with a significant increase in cumin area as mentioned above and it is clear in the figure. At the higher cumin price assumed in the scenario, water saved amounts to about 480, 240 and 175 million CM in HAG, RAG and DEG respectively, which corresponds to 13%, 7% and 7% reduction relative the reform baseline results respectively.

Figure 4.7. Impact of cumin price increase on water use



Source: study results

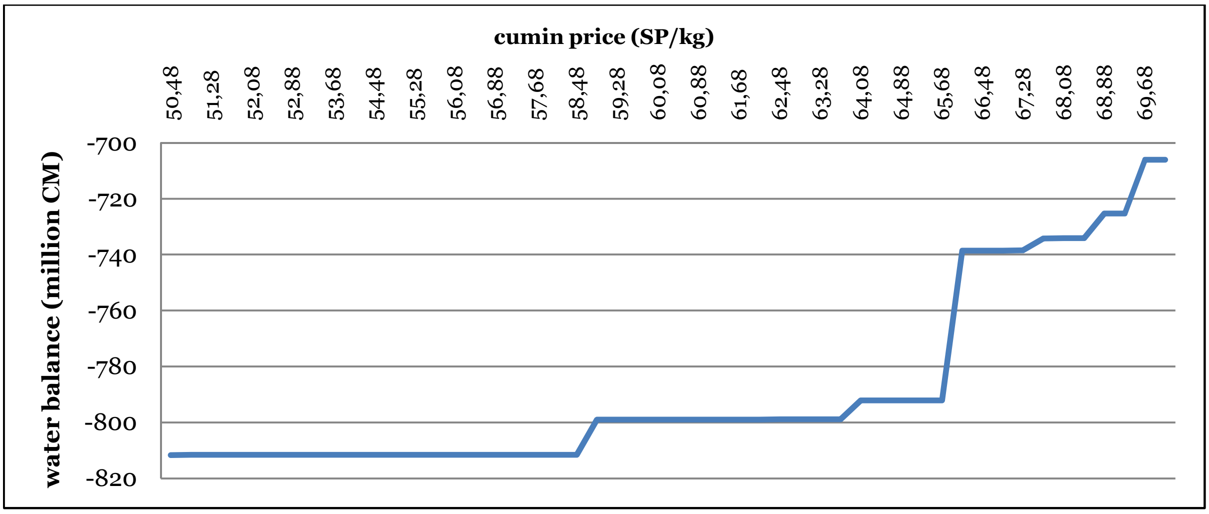
Figure 4.8. Impact of cumin price increase on cropping patterns



Source: study results

Water balance at AKB level is demonstrated in Figure 4.3, water deficit decreases steadily along with the increase in cumin price, reflecting that it is the consequence of the expansion of cumin cultivation at the expense of other crops that are more irrigation demanding than cumin. The shape of **Figure 4.9** would make more sense when it is combined with changes in cropping patterns in the three governorates of DERAHA. At low prices of cumin, water saving is due to wheat substitution for cumin, which is evident in **Figure 4.2**. However, at higher levels of cumin price, other crops start to get substituted for cumin, a clear example of that is cotton whose total area in DERAHA starts to decline as cumin price reaches about 65 SP (**Figure 4.8**).

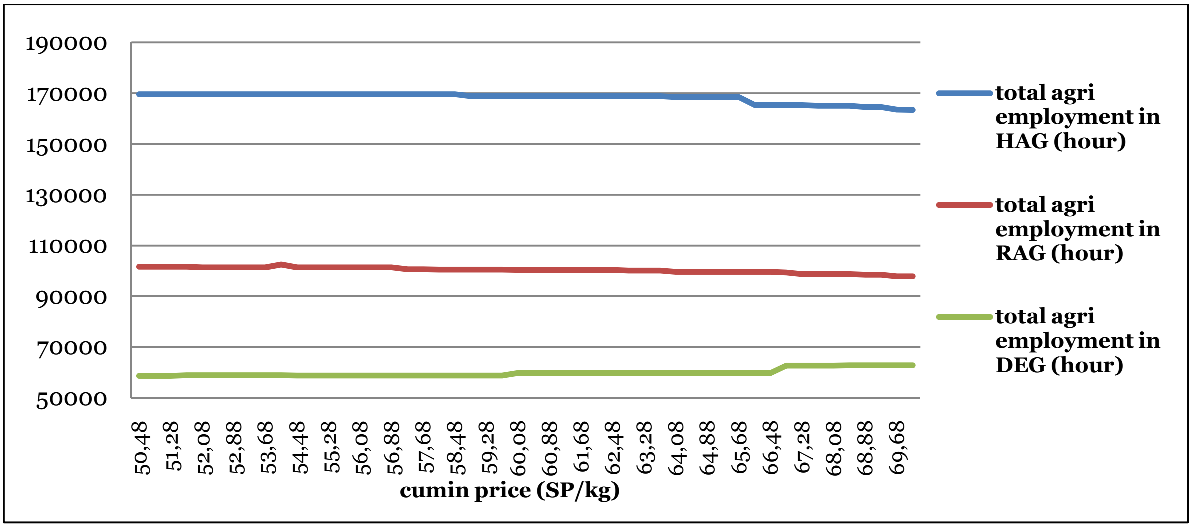
Figure 04.9. Impact of cumin price increase on water balance in AKB



Source: study results

Water saving increases by about 105 million CM at the highest cumin price assumed in the scenario in comparison with water saved by the previous scenario that only entails stabilising cumin price at its assumed market mean. This means that at such a price level, a significant water deficit will remain doubting the sufficiency of such a scenario to solve by itself the problem of water deficit in AKB.

Figure 04.10. Impact of cumin price increase on total agricultural employment



Source: study results

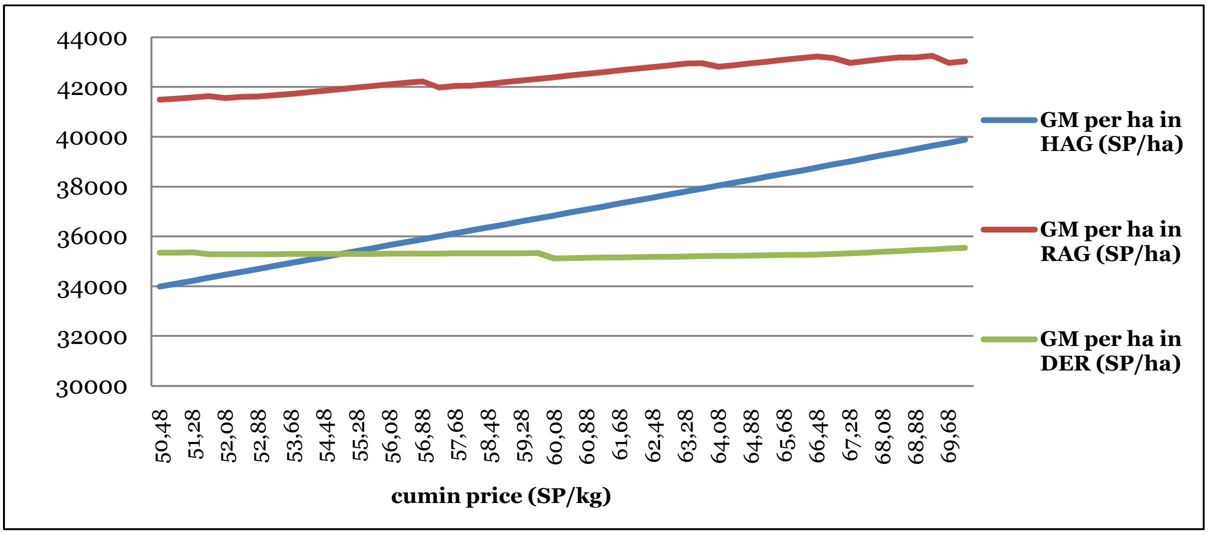
The impact f this scenario on agricultural income and employment in the three governorates of DERAHA is verified in **Figures 4.10** and **4.11**. No apparent negative impact on employment is observed as cumin price goes up although a slight reduction is witnessed in HAG, it seems that at a high level of cumin price, it starts to substitute in HAG crops that are more labour-intensive such cotton. This is not the case in RAG and DEG where the latter observes a slight increase in employment since cumin is also a labour intensive crop. Interesting is the impact on agricultural incomes which seem to increase steadily at a constant growth rate in each governorate although the rate of income growth is different from one governorate to the other. In fact, the low rate of income growth in DEG demonstrates the ineffectiveness of this scenario if the objective is to improve farming income in DEG.

Figure 04.11. Impact of cumin price increase on aggregate agricultural incomes

Source: study results

Figures 4.12, **4.13**, **4.14** and **4.15** illustrate the impact of cumin price increase on the productivity of factors of production. **Figure 4.12** demonstrates that this scenario is not effective if the objective will be the improvement of land productivity in DEG where GMs per hectare remain constant regardless of the level of cumin price. On the other hand, land productivity improves progressively in HAG at a quite high rate, which is one other sign of the positive impact of such a scenario in HAG. In RAG, land productivity improves generally although at a fluctuating rate, indicating that cumin faces there some competition from other crops.

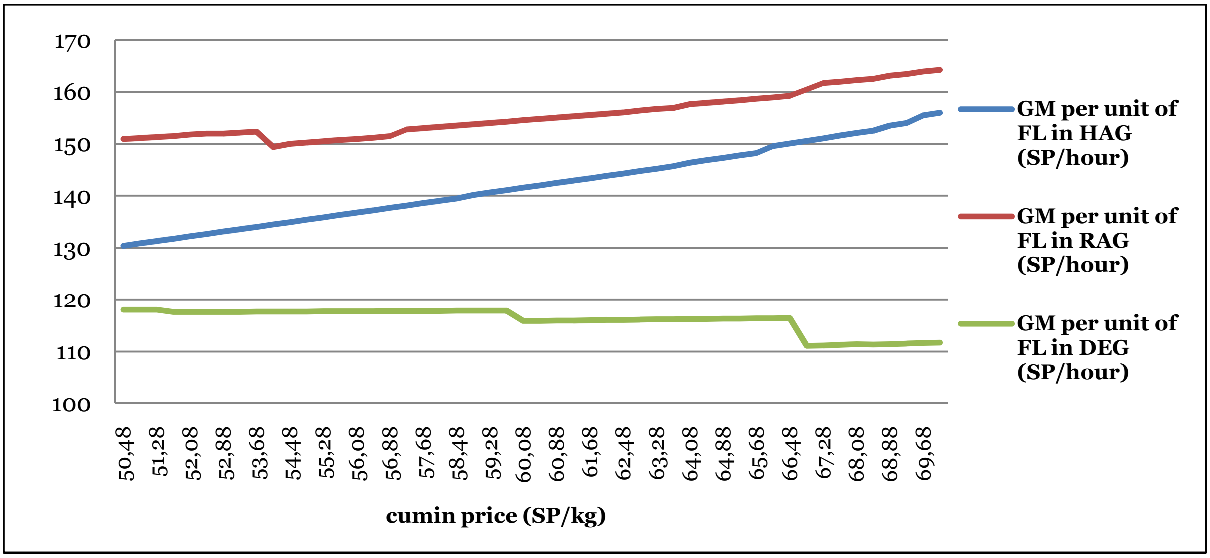
Figure 04.12. Impact of cumin price increase on GM per hectare



Source: study results

The impact of cumin price increase on labour productivity is similar to that of land productivity although an apparent negative correlation is observed in DEG. Productivity of family labour is the highest in RAG and it is the lowest in DEG. This is because farmers in DEG, since they have generally small holdings, use much family labour compared to those of HAG and RAG, while the latter has the lowest rate of family labour use (**Figure 4.13**). Surprisingly, the productivity of total labour is the highest in DEG followed by RAG, while HAG comes at the end. This is because farmers in HAG and RAG rely much more on hired labour (**Figure 4.14**).

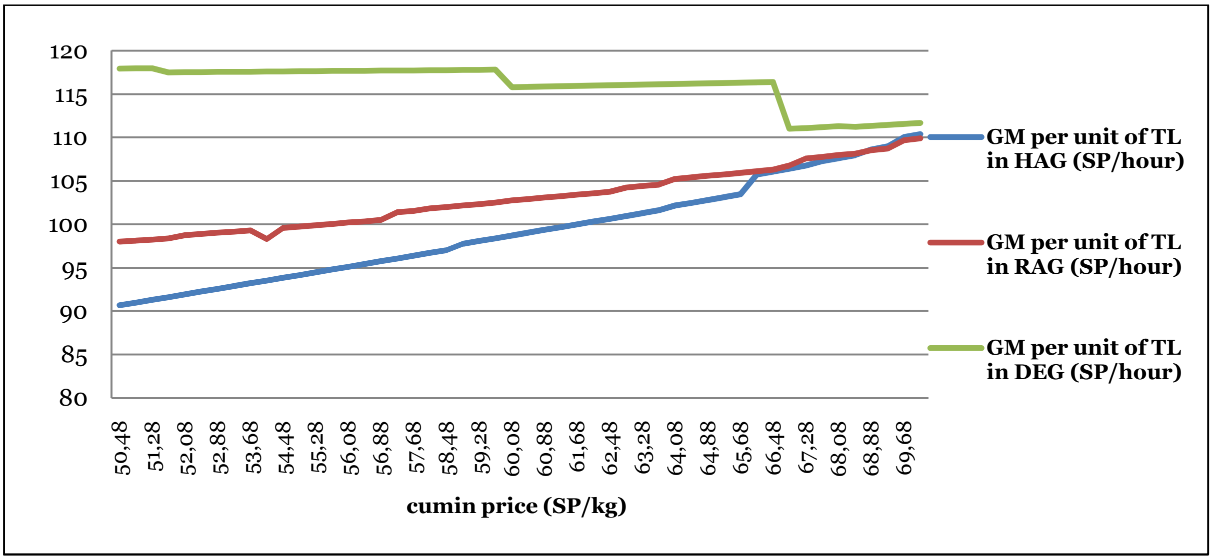
Figure 04.013. Impact of cumin price increase on GM per unit of family labour



Source: study results

One interesting observation is the equalisation of returns to total labour in the three governorates when cumin price reaches the highest assumed value in the scenario. The increase of labour productivity in HAG and RAG is a consequence of income rise only since employment remains almost constant in these two governorates. However, in DEG while income goes down for the highest values of cumin price, agricultural employment goes up causing this apparent reduction in labour productivity.

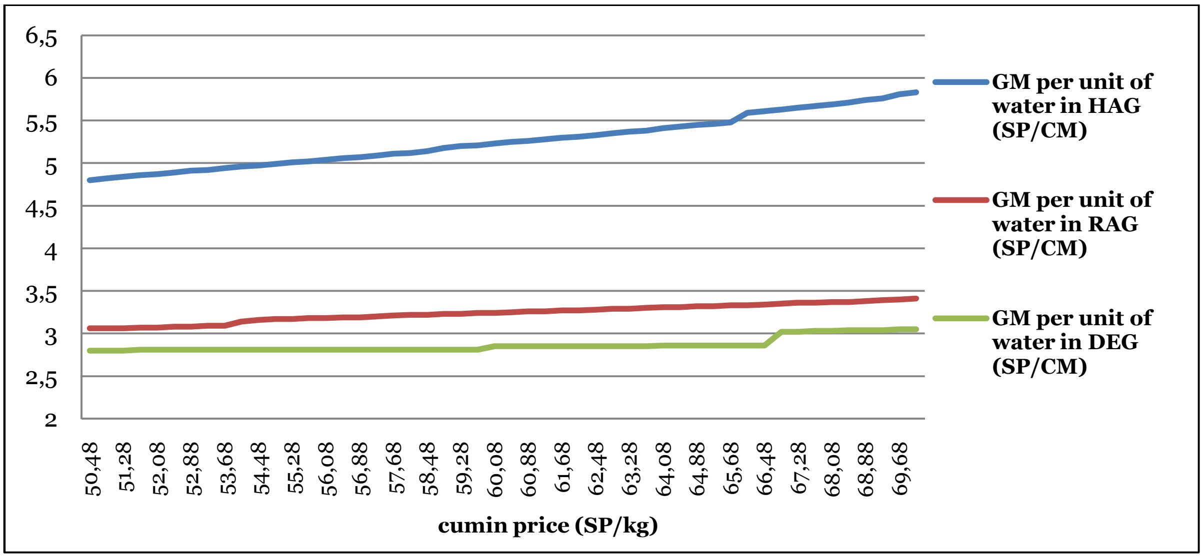
Figure 04.14. Impact of cumin price increase on GM per unit of total labour



Source: study results

Figure 4.15 illustrates the evident positive impact that the increase of cumin price has on water productivity. This is expected since the scenario demonstrates a reduction in water use, coupled with an increase in agricultural income. The **Figure** shows also that the efficiency of water use is always higher in HAG where water problem is more serious, which may indicate that farmers in HAG do better than farmers in RAG and DEG in allocating their irrigation water in an efficient way given the technology they have. This signs there may be some space for improving farm management in the areas where water use efficiency is lower.

Figure 4.15. Impact of cumin price increase on GM per unit of water use



Source: study results

4.2.3. Impact of giving credit on a per-hectare basis decoupling it from crops

This simulation aims at measuring the impact of eliminating the distortion in the credit policy that favours now the strategic crops. This simulated policy will allow providing credit on the basis of the total farm size and not in function of the cultivated crops. To perform this scenario, some values of the coefficient of cash anticipation reported in **Table 3.2** are changed in the way that makes the values of coefficient α_c identical to those of coefficient β_c. In addition, inequality [3.19] is modified to become as follows:

$$\sum_c \sum_f \sum_i \sum_w \alpha_c * X_{c,i,w} * In_{f,c,i} * Pr_{f,c} + \sum_t \sum_c \sum_i \sum_w \alpha_c * X_{c,i,w} * Mp_{c,i,t} + \sum_c \sum_i \sum_w \beta_c * X_{c,i,w} * Dq_{c,i,w} * Dp + tHlabt * Wh \leq Cap + L * Cdt * (1 + Ir) \qquad [4.5]$$

Where:

Cdt: is the amount assumed to be available per hectare from the ACB at the official interest rate Ir, while all other parameters of the inequality are unchanged and defined in **section 3.2**.

Table 4.14 illustrates the impact of this scenario on water use and cropping patterns in the three governorates of DERAHA. The most important observation from the table is that the impact is negligible in almost all governorates for both cropping patterns and water use. The only noticeable changes are for the areas of intercalary crops and other winter crops, in which the former increases by 15% while the latter decreases by 18%. However, we can easily neglect these changes knowing that the combined area of these two groups of crops does accounts only to less than 5% of the total cropped area.

Knowing that the impact of this simulated policy is negligible on cropping patterns and water use, we can conclude that it is so also for average income, income stability and agricultural employment, which means also that returns to land, labour and capital are not expected to change considerably. This conclusion allows us to infer that the current credit policy, although favours strategic crops, has a very light effect on farmers' decision making process in the presence of the pricing and delivery policy that heavily favours strategic crops.

Table 4. 14. Impact of eliminating credit policy distortion on water use and cropping patterns

	reform baseline	New credit policy scenario	% change
Water use (million CM)			
In HAG	3575	3575	0.00%
In RAG	3391	3397	0.18%
In DEG	2473	2473	-0.02%
Wheat area (ha)			
In HAG	341933	342116	0.05%
In RAG	134983	135829	0.63%
In DEG	109578	109581	0.00%
Cotton area (ha)			
In HAG	87447	87447	0.00%
In RAG	60148	60148	0.00%
In DEG	22906	22903	-0.01%
Sugar beet area (ha)			
In RAG	4958	4958	-0.01%
In DEG	3701	3701	0.01%
Maize area (ha)			
In HAG	398	398	-0.01%
In RAG	30092	30092	0.00%
In DEG	39498	39498	0.00%
Intercalary crops area (ha)			
In HAG	2871	2868	-0.09%
In RAG	1963	2269	15.61%
In DEG	13987	13992	0.03%
Other winter crop area (ha)			
In HAG	12872	12689	-1.42%
In RAG	4594	3748	-18.41%
In DEG	6189	6189	0.00%
Total cropped area (ha)			
In HAG	445521	445518	0.00%
In RAG	236738	238641	0.80%
In DEG	195859	195864	0.00%

Source: study results

4.2.4. Impact of decoupling the subsidy of cotton irrigated from wells

As explained in **section 4.1.1**, the GOS decided recently to give farmers irrigating cotton from private wells a subsidy per hectare of cotton as a compensation for the increased price of diesel that took place in 2008, which significantly raised the pumping costs of water. This last scenario aims to measure the impact of decoupling this current subsidy from cotton production, while farmers will still receive the same amount of compensation, but given on the basis of the farm size. The rationale of this scenario is that cotton is an irrigation-intensive crop and so linking a subsidy to its production may exacerbate the water scarcity problem. Therefore, we aim to predict if there will be a significant amount of water saved if the subsidy is decoupled from cotton production. To perform the scenario, equation [4.1] must be modified as to become as follows:

$$R = \sum_j P_j * Ep_j + L * Sd * Pw \qquad [4.6]$$

Where:

Sd: is the amount of subsidy per hectare given to farmers who use private wells for irrigation (SP)

L: is the farm size (ha),

Pw: is the dummy variable Pw takes the value of one if the relevant farm is irrigated from private wells, zero otherwise.

All other terms of the equation [4.6] are unchanged and explained in **section 3.2**.

Table 4. 15. Impact of decoupling the subsidy given to cotton irrigated from private wells

	reform baseline	New subsidy system scenario	% change
Water use (million CM)			
In HAG	3575	3575	0.00%
In RAG	3391	3397	0.18%
In DEG	2473	2473	-0.02%
Wheat area (ha)			
In HAG	341933	342608	0.20%
In RAG	134983	140747	4.27%
In DEG	109578	111217	1.50%
Cotton area (ha)			
In HAG	87447	86569	-1.00%
In RAG	60148	54362	-9.62%
In DEG	22906	21267	-7.15%
Sugar beet area (ha)			
In RAG	4958	4958	-0.01%
In DEG	3701	3701	0.01%
Maize area (ha)			
In HAG	398	398	-0.01%
In RAG	30092	37410	24.32%
In DEG	39498	41092	4.03%
Intercalary crops area (ha)			
In HAG	2871	2881	0.34%
In RAG	1963	1969	0.30%
In DEG	13987	14436	3.21%
Other winter crop area (ha)			
In HAG	12872	13075	1.58%
In RAG	4594	4617	0.49%
In DEG	6189	5315	-14.12%
Total cropped area (ha)			
In HAG	445521	445531	0.00%
In RAG	236738	245658	3.77%
In DEG	195859	197902	1.04%

Source: study results

Table 4. 16. Impact of decoupling the subsidy given to cotton irrigated from private wells on employment and income

Governorate	HAG	RAG	DEG	total DERAHA
Total agricultural employment (thousand hour)				
Reform baseline results	144765	95787	58645	299197
Scenario results	144100	91912	57536	293548
% change	-0.46%	-4.05%	-1.89%	-1.89%
Hired agricultural employment (thousand hour)				
Reform baseline results	36429	33456	66	69951
Scenario results	35882	31218	66	67166
% change	-1.50%	-6.69%	0.42%	-3.98%
Sum of Gross Margins (million SP)				
Reform baseline results	13402	9780	6916	30098
Scenario results	13555	9755	6965	30275
% change	1.14%	-0.26%	0.71%	0.59%
Sum of Certainty Equivalents (million SP)				
Reform baseline results	13261	9710	6558	29529
Scenario results	13412	9684	6608	29704
% change	1.14%	-0.27%	0.76%	0.59%

Source: study results

Table 4.15 illustrates the impact of this scenario on water use and cropping patterns in the three governorates of DERAHA. Obviously, although cotton area goes down noticeably, water change is almost zero. This is because the water saved from decreasing cotton area is used to expand other crops, namely wheat and maize. This implies that decoupling this subsidy from cotton production were not sufficient if water saving would be the objective to be achieved.

Table 4.16 shows the impact that this scenario may have on agricultural incomes and employment in DERAHA. Average income level and its stability are not expected to change much since all changes do not account to 2%. Impacts on employment, on the other hand, is evident in RAG where the decrease in cotton area is the highest since cotton is a very labour-intensive crop.

Chapter 5. Conclusions

5.1. Introduction

Agricultural policy in Syria, as many of its counterparts in other countries, continues striving to achieve several contradictory objectives through compromising sets of policy instruments. The main objectives of the agricultural policy as defined in the Syrian Agricultural Strategy for the period 2001-2010 concern, at the same time, improving farmers' incomes, increasing self-sufficiency of basic staple foodstuffs and conserving scarce natural resources, namely water (NAPC 2006). According to this strategy, the GOS has been using mainly the pricing policy to achieve the first and the second objectives, while very little had been done to achieve the objective related to water conservation. On the contrary, there was a period in which, farmers were encouraged to use water irrationally through a random digging of wells to expand irrigated cultivation.

However, the GOS recently declared a national plan to convert all irrigated areas in the Country to modern irrigation as a consequence of increased awareness on the issue of water scarcity in the Country and at the regional level as well. In the meantime, several suggestions have been made to change the structure of current cropping patterns in the Country in an attempt to switch some areas from water-intensive crops to others that have lower irrigation requirements. Nevertheless, in all cases, the question of the impact of such structural changes in the agricultural sector on farmers' incomes and their stability remains legitimate, whether such changes are caused by modernising the irrigation system, modifying the current cropping patterns, or any combination of both.

This thesis aims at measuring the impact of agricultural policy on water use in the north-east of Syria (DERAHA), while assessing the potential risks on farmers' incomes and their stability that may be caused by any proposed alternative policy scenario. The rationale behind choosing DERAHA is evident since its agriculture is most dependent on strategic crops whose prices are set by the GOS and their outputs are totally or partially delivered to parastatal agencies. Therefore, it is expected that any new alternative policy will have greater impact in farming incomes in this region. In addition, water scarcity problem, which is of concern in most areas of the Country, is well observed in DERAHA especially in HAG where AKB experiences a high hydraulic deficit.

A mathematical programming model using the Expected Utility Theory applied through mean-variance principle, combined with a set of representative farms, is used to estimate farm incomes and water use under different conditions. In particular, the model results of the study reference year (2005) are compared to the results of a new baseline which takes into account all policy reforms that have taken place in the period 2005-2009. Then this new baseline (reform baseline) is used to simulate new possible alternative policies from which considered in this thesis are the impact of modernising the irrigation system, stabilising and supporting cumin price, decoupling agricultural short-term credit from strategic crops, and decoupling the subsidy given currently to cotton irrigated from private wells.

5.2. Summary of major results

The comparison between the baseline results of 2005 and the reform baseline results shows that the recent reform is expected to have light impacts on water use and farming income. Changes in water use is less than 5% in the entire region although it is negative in HAG while it is positive in RAG and DEG. However, changes in income level and stability are more noticeable in the three governorates and characterised by positive changes. The highest increase in average income is in DEG (15% almost) followed by RAG (11% almost) while the increase is lowest in HAG (3% almost). The impact on the stability of income has also the same order, but it is of interest to mention that the impact of the recent policy reforms due to stabilising maize price is higher on income stability than on average income in the three governorates, in which it reaches about 19%, 13% and 4% in DEG, RAG, and HAG respectively.

Moreover, the results of other alternative policy scenarios reveal several interesting policy implications that are not obvious at the first sight. They illustrate that the adoption of modern irrigation techniques by all farms of the region does not solve the water scarcity problem in AKB where there will still be a deficit of more than eight hundred CMs due to two facts: first, the present efficiency of modern irrigation techniques at the farm level is very low compared to that in research stations. Second, water saved by the adoption of modern irrigation may be used to expand irrigated land. The latter observation is plainly observed in HAG where currently intercalary cropping is constrained by the scarcity of irrigation water. As irrigation efficiency increases, per unit irrigation costs also decline and then a major part of the water saved gets used to expand irrigated cultivation of intercalary crops.

In addition, the model results allow us to evaluate and to assess the effectiveness of various public policy instruments, and to reveal which of them affect the decision-making of farmers the most. They show that decoupling the official credit provided by the ACB from strategic crops would have negligible effects on cropping patterns and water use consequently. Furthermore, decoupling the subsidy that is presently linked to cotton irrigated from private wells has also small effects on water use although some changes in the cropping patterns are observed in which cotton area goes down while the areas of wheat and maize go up. Here again, the water saved from decreased cotton area is used to expand those of wheat and maize. On the other hand, stabilising cumin price produces noticeable changes whether in cropping patterns or/and in water consumption. The latter is reduced by some 10% in HAG mainly as a result of expanding cumin cultivation at the expense of wheat, but also at the expense other winter crops in RAG and DEG where water use is reduced slightly. Consequently, the model results affirm that price policy is potentially the instrument that affects farmers' decision the most. If effective in stabilizing price for water saving crops, this may be an important tool to combine farm welfare improvement with increased sustainability in water use.

5.3. Merits and limitations of the study

The first limitation of the study is that the analytical model used in this study needs a large amount of data, which limits its applicability by individual researchers unless they have access to census data or at least they have resources to conduct a large *ad hoc* survey. Conducting such studies without having sufficient data detailed at the farm level forces researchers to rely on *ad hoc* assumptions about values of technical parameters that may be unrealistic, and in order to calibrate the model results on the observed behaviour they may have to impose further assumptions without a scientific basis.

In addition, our model, in its current design, does not allow us to assess the costs of the proposed alternative policies, which limits our ability to make precise recommendations as the cost of any policy is a very important element and a new policy is only justified if its costs are overweighed by its benefits.

One other important limitation is that the model representativeness of the farming sector in DERAHA is not perfect. For the purpose of simplification, many assumptions are maintained and some of them may not be realistic. The way the matrixes of technical coefficients are modelled imply that farmers know in advance the yields to be harvested and the level of inputs to be applied regardless of the impact of subsequent events that may motivate farmers to change their production plans during the agricultural season. The way prices of agricultural products are modelled imply that farmers are aware of the assumed states of nature and of the values that prices take in each of them with the associated probability, which is a very strong assumption to acknowledge. In addition, the objective function assumes that farmers seek to avoid income fluctuations regardless of whether they are negative or positive, which may not be necessarily true.

These comments mean that the interpretation of the results is performed with care especially if policy recommendations are on stake.

However, this does not mean that the model is far from being representative of the farming sector. It is acceptable to assume that farmers try to maximise profits but they are conditioned by risky and uncertain environment. Therefore, given the amount and the types of data available, we believe that our model is the best way to capture the basic elements of the agricultural irrigated sector in DERAHA taking into consideration the component of risk and uncertainty. As we mentioned right above, the model helps revealing policy implications that are not evident, as it allows to solve problems with conflicting objectives such as to know how we can reduce water consumption without penalising farmers' incomes.

One other merit of such models is that they assist the modellers to think comprehensively and deeply of the technical aspects of farm management, that is a very important issue in the field of applied economics research. Learning these technical details is the key for improving our understanding of farmers' behaviour, which will allow us to improve our modelling skills and so produce more reliable results and recommendations.

The model has also the merit of being quite flexible, and so it can be easily improved if more reliable data are available. The way it is constructed using the GAMS software allows changing data matrix without changing the model structure. In addition, the model is constructed with the assistance of the command *loop* which allows the structure of the model to be general, while a set of dummy variables links this general structure to every single farm. Therefore, the model can be solved for all farms together without the need to change the model structure every time. This allows solving for large number of farms in a very short time, and therefore, allows including other Syrian governorates in the model when their data become available without changing the general structure of the model.

5.4. Suggestions for future research

Some of the limitations highlighted above can be overcome by further improvements of the analytical model. The costs of the alternative proposed policy can be included in the model by adjusting the latter to take into account multiple objective functions. This means transforming the model to a sectoral structure as explained in Hazell and Norton (1986), in which a set of constraints of government budgetary resources is introduced. Another way of improving the model structure is through making it a general equilibrium model in which prices are determined endogenously. However, this requires extending the model to include all the Syrian agricultural sector which requires quite large amount of data, but also significant modification of the model structure.

However, the model in its present structure can be used for conducting further research. Many possible policy scenarios can be performed, from which we only did four, which we currently consider the most important. However, other interesting scenarios might be interesting in the future depending on the conditions of relevant commodity markets at the international level. Here, scenarios of changing prices of some strategic crops such as wheat and cotton may be interesting if prices of these commodity change significantly at the world market. In addition, the model can be also used to conduct joint scenarios, modernising the irrigation system while stabilising cumin price is one example. Another interesting example maybe abolishing the subsidy linked to cotton irrigated from wells and introducing a new subsidy system in which the latter is linked to some policy objectives such as reducing summer cropping for the sake of saving water. Another kind of scenarios is the introduction of new crops that may assist in realising some policy preferences such as saving irrigation water; however, the technical parameters of these crops must be known with high precision if results are to be reliable.

Bibliography and References

- Baquet, A., Hambleton, R., & Jose, D. (1997). "Introduction to Risk Management", the Risk Management Agency of the U.S. Department of Agriculture (USDA), 20 pp, available online.
- Bernoulli, D. (1954). "Exposition of a new theory of the measurement of risk", *Econometrica*, Vol. 22, no. 1, pp. 23-36.
- Buysse, J., Huylenbroeck, G.V., & Lauwers, L. (2007). "Normative, positive and econometric mathematical programming as tools for incorporation of multifunctionality in agricultural policy modelling", *Agriculture, Ecosystems and Environment*, no. 120, pp. 70-81.
- Cafiero, C. (2005). "Problemi e prospettive per una moderna gestione del rischio nell'agricoltura europea". *Economia e Diritto Agroalimentare*, no. 2, pages 135-150.
- Cafiero, C. (2004). "Ci si può fidare dei modelli matematici nelle analisi di politica agraria?", *Politica Agricola Internazionale*, no. 1-2, pp. 23-42.
- Cafiero, C., Capitanio, F., Cioffi, A., & Coppola, A. (2006). "Rischio, crisi e intervento pubblico nell'agricoltura europea". *Politica Agricola Internazionale*, no. 4, 2006. pages 11-41.
- Cafiero, C. & Cioffi, A. (2004). "The changing role of public policies in farm income stabilization", in: *Income Stabilization in Agriculture: The Role of Public Policies*, edited by: C. Cafiero and A. Cioffi, Proceedings of the 86th EAAE seminar "Agricultural Income Stabilization: what role should public policies play?" Anacapri, Italy, October 21-22, 2004, Edizioni Scientifiche Italiane, Naples.
- Carruthers, I. (1996). "Economics of irrigation", In L.S. Pereira et al. (eds), *Sustainability of Irrigated Agriculture*, pp 35-46.
- Caswell, M.F. & Zilberman, D. (1986). "The effects of well depth and land quality on the choice of irrigation technology", *American Journal of Agricultural Economics*, Vol. 68, no. 4, pages 798-811.
- CBS. (2006). "Total results and characteristics of population and houses", results of the 2004 national census conducted in 2004 by the Syrian Central Bureau of Statistics (CBS).
- Cernea, M. (1997). "Hydropower dams and social impacts: a sociological perspective", Environmental Department Papers, *Social Assessment Series* 044, Washington DC: The World Bank, 30 pp, available online.
- Chambers, R.G. & Quiggin, J. (2000). *Uncertainty, Production, Choice, and Agency: the State-Contingent Approach*. Cambridge University Press, 373 pp.
- Chavaz, J.P. (2004). *Risk Analysis in Theory and in Practice, Amsterdam*, Elsevier.
- Chavas, J.P. & Holt, M.T. (1996). "Economic behavior under Uncertainty: a joint analysis of risk preferences and technology", *The Review of Economics and Statistics*, Vol. 78, no. 2, pp. 329-335.

- Coble, K.H. (2009). "Risk management in agriculture – a holistic conceptual framework", The OECD Working Group on Agricultural Policies and Markets, 59 pp, available online.
- Coble, K.H. & Barnett, B.J. (2008). "An assessment of risk exposure in agriculture – a literature review", The OECD Working Group on Agricultural Policies and Markets, 64 pp, available online.
- Cornish, G., Bosworth, B., Perry, C., & Burke, J. (2004). "Water charging in irrigated agriculture", HR Wallinggford and Food and Agriculture Organization (FAO), Rome, pp 82, available online.
- Cummins, G. (2000). "Livestock sub-sector", FAO Project GCP/SYR/006/ITA, National Agricultural Policy Centre (NAPC), Damascus, 136 pp., available online
- De Frahan, B.H., Buysse, J., Polomé P., Fernagut, B., Harmignie, O., Lauwers, L., Van Huylenbroeck, G., & Van Meensel, J. (2007). "Positive Mathematical programming for agricultural and environmental policy analysis: review and practice", chapter 8 in: *Handbook of Operations Research in Natural Resources*, edited by Weintraub, A., Romero, C., Cemare, T.B., Epstein, R., & Miranda, J., Springer, pp. 129-154.
- De Fraiture, X.C., Amarasinghe, U., Rosegrant, M., & Molden, D. (2004). "Does food trade save water: the potential role of food trade in water scarcity mitigation", International Water Management Institute (IWMI), 7 pp, available online.
- Dercon, S. (2002). "Income risk, coping strategies and safety nets", *World Bank Research Observer,* 17 (2), Pages 141-166.
- De Stefano, F. (1988). *Problemi di Politica Agraria*, edition (a cura di), Società Editrice il Mulino, Centro di Specializzazione e ricerche Economico-Agrarie per il Mezzogiorno.
- Ellis, F. (1993). *Peasant Economics*, second edition, Cambridge University Press, 309 pp.
- Ellis, F. (1992). *Agricultural Policies in Developing Countries*, Cambridge University Press, 357 pp.
- Eswaran, M. & Kotwal, A. (1990). "Implication of credit constraints for risk behaviour in less developed countires", *Oxford Economic Papers*, Vol. 42, pp. 473-482.
- Eswaran, M. & Kotwal, A. (1989). "Credit as insurance in agrarian economies", *Journal of Development Economics*, Vol. 31, pp. 37-53.
- FAO & IFAD. (2006). "Water for Food, Agriculture and Rural Livelihoods", Chapter 7 in: *Water a shared responsibility: the United Nations world water development Report 2*, pp. 244-273, available online.
- Fafchamps, M. (2003). *Rural Poverty, Risk and Development*, Edward Elgar Publishing, 262 pp.
- Forni, N. (2001). "Land tenure systems: structural features and policies. FAO Project GCP/SYR/006/ITA, the National Agricultural Policy Centre (NAPC), Damascus, 69 pp, available online.
- Freund, R.J. (1956). "Introduction of risk into a programming model", *Econometrica*, Vol. 24, no. 3, pp. 254-263.
- Gadgil, S., Seshagiri Rao, P.R., Narahari Rao, K. (2002). "Use of climate information for farm-level decision making: rainfed groundnut in southern India", *Agricultural Systems*, Vol. 74, pp. 431-457.
- Garces-Restrepo, C., Vermillion, D., & Munoz G. (2007). "Irrigation management transfer: worldwide efforts and results", Food and Agriculture Organisation (FAO), Rome, in collaboraton with International Water Management Institute (IWMI), pp 62, available online.

- GCASR, (2006). *The Annual Abstract of Water Requirements of the Agricultural Plan*, General Commission for Agricultural Scientific Research Damascus (GCASR), 329 pp (In Arabic).
- Hamza, R. (2004). "Syria farming systems: semi-humid and irrigated farming systems zone of the northern and north-eastern plains", National Agricultural Policy Centre (NAPC), unpublished working papre, 68 pp., available in NAPC upon request.
- Hardaker, J.B. (2000). "Some issues in dealing with risk an agriculture", working paper series in agriculture and resource economics, University of New England, Graduate School of Agricultural and Resource Economics, 18 pp, available online.
- Hardaker, J.B., Huirne, R.B.M., Anderson, J.R. & Lien, G. (2004). *Coping with Risk in Agriculture,* second edition, CABI Publishing, 332 pp.
- Harwood, J.L., Heifner, R., Coble, K.H., Perry, J., & Somwaru, A. (1999). "Managing risk in farming: concepts, research and analysis", Economic Research Resvice, the U.S. Department of Agriculture, Report no. 774, available online.
- Hasnip, N., Vincent, L., & Hussein, K. (1999). *Poverty reduction and irrigated agriculture.* International programme for Technology and Research in Irrigation and Drainage (IPTRID) and Food and Agriculture Organization (FAO), Rome, pp 19, available online.
- Hazel P. B. R. & Norton R. D. 1986. Mathematical Programming for Economic Analysis in Agriculture, MacMillan Publishing Co., New York, 400 pp.
- Holzman, R., & Jorgensen, S. (2001). "Social risk management: a new conceptual framework for social protection, and beyond", *International Tax and Public Finance*, Vol. 8, pp 529-556.
- Howitt, R.E. (1995). "Positive mathematical programming", *American Journal of Agricultural Economics*, Vol. 77, no. 2, pp. 329-342.
- Huirne, R.B.M., Meuwissen, M., Hardaker, J.B., & Anderson, J.R. (2000). "Risk and risk management in agriculture: an overview and empirical results", *International Journal of Risk Assessment and Management*, 1 (2000), pp 125-136.
- Hull, J.C. (1996). *Options, Futures, and Other derivatives*. Prentice Hall.
- Huppert, W. & Urban, K. (1999). "Institutional analysis of water delivery and maintenance servce provision in irrigation: the example of the Jordan Valley", Division 45, Rural Development, MAINTAIN, Case Study no. 3, Eschborn, Germany, GTZ, pp 77.
- IFAD. (2001). *Rural Poverty Report 200): the challenge for ending poverty*, International Fund for Agricultural Development (IFAD), Oxford University Press, available online.
- Jaffer, J. (1999). "Microfinance and the mechanics of solidarity lending: Improving access to credit through innovations in contract structures", paper series of Harvard Law School John M. Olin Center for Law, Economics and Business Discussion, 31 pp.
- Just, D.R. & Just, R.E. (2009). "Practical application and discernability of risky choice models" working paper, 28 pp, available online.
- Just, R.E. (2008). "Distinguishing preferences from perceptions for meaningful policy analysis", *American Journal of agricultural Economics*, Vol. 90, No. 5, pp. 1165-1175.
- Just, R.E. & Pope, R.D. (2003). "Agricultural risk analysis: adequacy of models, data, and issues", *American Journal of Agricultural Economics*, Vol. 85. No. 5, pp. 1249-1256.
- Kahneman, D. & Tversky, A. (1979). "Prospect theory: an analysis of decision under risk", *Econometrica*, Vol. 47, no. 2, pp. 263-291.
- Kutcher, G.P. & Scandizzo, P.L. (1981). *The Agricultural Economy of Northern Brazil*, Johns Hopkins Unin. Press, Baltimore, MD, the USA, 271 pp.

- Lançon, F. (2005). “Comparative advantages study”, FAO Project GCP/SYR/006/ITA, National Agricultural Policy Centre (NAPC), Damascus, 82 pp., available online.
- Lipton, M., Litchfield, J., Blackman, R., De Zoysa, D., Qureshy, L., Waddington, H. (2003). “Preliminary review of the impact of irrigation on poverty with special emphasis on Asia”, Food and Agriculture Organization (FAO), Rome, pp 46, available online.
- Long, R.G., White, M.C, Friedman, W.H, & Brazeal, D.V. (200). “The ‘qualitative’ versus ‘quantitative’ research debate: a question of metaphorical assumptions?”, *International Journal of Value-Based Management*, no. 13, pp. 189-197.
- MAAR. (2005). *Land Use Balance,* The Ministry of Agriculture and Agrarian Reform (MAAR), the Department of Statistics and Planning, Damascus 74 99.
- MAAR. (1994). *National Farm Data Handbook,* Ministry of Agriculture and Agrarian Reform (MAAR), Damascus 86 pp.
- MAAR Statistical Abstracts. Reports issued by the Ministry of Agriculture and Agrarian Reform on an annual basis.
- Malevolti, I. (1999). “Olive and olive oil sub-sector”, FAO Project GCP/SYR/006/ITA, National Agricultural Policy Centre (NAPC), Damascus, 71 pp., available online.
- Moschini, G., & Hennessy, D. (2001). “Uncertainty, risk, aversion, and risk management for agricultural producers”, in: *Handbook of Agricultural Economics,* edited by: B. Gardner and G. Rausser, Vol. 1A, Elsevier Science Publishing.
- Müller, M. & Djannibekov, N. (2009). “Calibration of an agricultural sector model for the region of Khorezm (Uzbekistan) based on survey data”, contributed paper for presentation at the International Association Agricultural Economics Conference, Beijing, China, August 16-22, 2009, available online.
- NAPC. (2006). “Mid-term review of Syrian Agricultural Strategy”, National Agricultural Policy Center (NAPC), Damascus, 110 pp, available online.
- NAPC. (2005a). “Economic incentives and policy options for sustainable water use in agriculture: the case of Al-Khabour basin, Syria*”,* National Agricultural Policy Center (NAPC), Damascus, 82 pp, available online.
- NAPC. (2005b). “An assessment of alternative price policy for cotton in Syria”, National Agricultural Policy Center (NAPC), Damascus, 28 pp, available online.
- Newbery, D.M.G. & Stiglitz, J.E. (1981). *The Theory of Commodity Price Stabilization*. Oxford, Clarendon Press.
- Parthasarathy, N.S. (2001). “Agricultural credit”, FAO Project GCP/SYR/006/ITA, the National Agricultural Policy Centre (NAPC), Damascus, 108 pp., available online.
- Parthasarathy, N.S. (2000). “Agricultural inputs liberalization”, FAO Project GCP/SYR/006/ITA, the National Agricultural Policy Centre (NAPC), Damascus, 131 pp., available online.
- Pulley, L.B. (1983). “Mean-variance approximations to expected logarithmic utility”, *Operations Research*, Vol. 31, no. 4, pp. 685-696.
- Quiggin, J. & Chambers, R.G. (2005). “The state-contingent approach to production under uncertainty”, working paper: R05#1, Risk & Sustainable Management Group, University of Queensland 18 pp.
- Quirino, P. & Howitt, R.E. (1998). “An analysis of ill-posed production problems using maximum entropy”, *American Journal of Agricultural Economics*, Vol. 80, no. 1, pp. 124-138.
- Rabin, M. (2000a). “Risk aversion and expected utility theory: a calibration theorem”, *Econometrica*, Vol. 68, no. 5, pp. 1281-1292.

- Rao, J.M. (2009). “Challenges facing World agriculture: a political economy prespective”, to be published in *Development and Change*.
- Rama, D. (2000). “Agricultural Marketing and Processing”, FAO Project GCP/SYR/006/ITA, the National Agricultural Policy Centre (NAPC), Damascus, 62 pp., available online.
- Rasmussen, S. (2006) . “Optimizing production under uncertainty: generalization of the state- contingent approach and comparison with the EV model”, Institute of Food and Resource Economics, Production and Technology Division, 30 pp., available online.
- Rasmussen, S. (2003) . “Criteria for optimal production under uncertainty: the state-contingent approach”, *The Australian Journal of Agricultural and Resource Economics*, Vol. 47, no. 4, pp. 447-476.
- Ray, I. (2002). Farm-level incentives for irrigation efficiency: some lessons from an Indian canal. *Water Resources Update*. Issue no. 121; January 2002, available online.
- Roberts, M.J., Osteen, C. & Soule, M. (2004). “Risk, government program, and the environment”, Economic research Service, the U. S. Department of Agriculture (USDA), Technical Bulletin Number 1908, 52 pp, available online.
- Robison, L. & Barry, P. (1987). *The Competitive Firm’s Response to Risk,* New York, MacMillan.
- Sadiddin, A. (2009a). “L’impiego e la valorizzazione delle risorsa idrica: i problem e i nuovi traguardi dell’agricoltura siriana”, a seminar presented at L’Istituto Nazionale di economia Agraria (I.N.E.A), Rome.
- Sadiddin, A. (2009b). “The foreseen impact of the recent policy reforms and other scenarios on water use in Syrian Arab Republic: the case of Al-Khabour basin”, National Agricultural Policy Centre (NAPC), Damascus, 28 pp, available online.
- Sadiddin, A. (2004). “Syria farming systems: farming systems of the central irrigated and rainfed plains and Al-Ghab”, National Agricultural Policy Centre (NAPC), unpublished working papre, 80 pp, available in NAPC upon request.
- Safi, H.S., (2006). “The state of modern irrigation in Syria and the best methods to develop it to serve agricultural development”, A Graduate Dissertation from the National Defence Institute, the Ministry of Defence of the Syrian Arab Republic, Damascus, 144 pp (in Arabic).
- Savage, L.J. (1954). *The Foundations of Statistics,* New York, Wiley.
- Skutsh, J., Evans, D., & Brabben, T. (1999). “Realizing the value of irrigation maintenance”, Food and Agriculture Organization (FAO), Rome, in collaboration with International Programme for Technology and Research in Irrigation and Drainage (IPTRID), pp 22, available online.
- SOFA. (2002)
- SOFA. (2007)
- Somi, G., Alshayeb, R., and Zyada, R. (2002). “Technical and economic effects of modern irrigation methods and results of research on water rational use in agriculture in the Syrian Arab Republic”, The National Workshop on Water Resources held in Al-Salamia, Hama. The Ministry of Agriculture and Agrarian Reform (MAAR), Damascus, 32 pp (in Arabic).
- Somi, G. (1997). “Special food security programme on water”, Ministry of Agriculture and Agriarian Reform (MAAR), FAO, Damascus, 12 pp (in Arabic).
- Starmer, C. (2000). “Developments in the non-expected utility theory: the hunt for a descriptive theory of choice under risk”, Journal of Economic Literature, Vol. 38, June 2000, pp. 332-382.

- UNDP. (2005). *Poverty in Syria: 1996-2004: Diagnosis and Pro-Poor Policy Considerations*, The United Nations Development Programme (UNDP), H. El Laithy and K. Abu-Ismail, June, available online.
- Upton, M. (2004). *The Economics of Tropical Farming Systems*, Cambridge University Press, 374 pp.
- Varela-Ortega, C. & Sagardoy, J.A. (2001). "Agricultural water use", FAO Project GCP/SYR/006/ITA, the National Agricultural Policy Centre (NAPC), Damascus, 150 pp, available online.
- Varela-Ortega, C. Sumpi, J.M., Garrido, A., Blanco, M., & Iglesias, E. (1988). "Water pricing policies, public decision making and farmers' response: implication for water policy", *Journal of Agricultural Economics*, Vol. 19, pages 193-202.
- Von Neuman, J. & Morgenstern, O. (1944). *Theory of Games and Economic behaviour*, Princeton, NJ, Princeton University Press.
- Ward, C. (2000). "The political Economy of irrigation water pricing in Yemen", *In* A. Dinar, ed. *The political economy of water pricing reforms*. ISBN 0-19-521594-X. World Bank. Oxford University Press, pp 381-394.
- Wattenbach, H. (2006). "Farming Systems of the Syrian Arab Republic", FAO Project GCP/SYR/006/ITA, National Agricultural Policy Center, Damascus, 145 pp, available online.
- Wehrheim, P. (2001). "Taxation and net transfers to the agricultural sector", FAO Project GCP/SYR/006/ITA, National Agricultural Policy Center, Damascus, 81 pp., available online.
- Westlake, M. (2001). "Strategic crops' sub-Sector", FAO Project GCP/SYR/006/ITA, National Agricultural Policy Centre (NAPC), Damascus, 84 pp., available online.
- Westlake, M. (2000). "Citrus sector", FAO Project GCP/SYR/006/ITA, National Agricultural Policy Centre (NAPC), Damascus, 95 pp., available online.
- World Bank. (2005). "Managing Agricultural Production Risk – Innovations in Developing Counties", The World Bank Agriculture and Rural Development Department, 74 pp, available online.
- Wright, B.D. (2004). "Why government crop insurance?", in: *Income Stabilization in Agriculture: The Role of Public Policies*, edited by: C. Cafiero and A. Cioffi, Proceedings of the 86th EAAE seminar "Agricultural Income Stabilization: what role should public policies play?" Anacapri, Italy, October 21-22, 2004, Edizioni Scientifiche Italiane, Naples.
- Zilberman, D. (1989). "The Appropriate Model for the Choice of Agricultural Inputs: Primal, Dual, or Other", paper presented at American Economists Association meeting, Atlanta GA, 13 pp.

Appendix: Model and Data

I.1. GAMS Model

```
$OFFUPPER OFFSYMLIST OFFUELLIST OFFSYMXREF OFFUELXREF
OPTION NLP = MINOS ;

sets
    i  iter    / 1*1 /
   rr  mantikas / 1*10 /
* mantika is the administrative unit that is lower than governorate
* governorate is the highest administrative unit in Syria (equivalent to regione * in Italy)
  agz  agro climatic zones / 1*5 /
  fff  maximum number of representative farms in a mantika / 1*15 /
    x  fixed factors and technology dummies of farming systems
                                          /cash, land, sprink,drip,number,agz,
                                          river, punet,pwell, cottonls,autsugls,
                                          winsugls,barlreq, rac /
$ontext
DEFINITIONS OF FIXED FACTORS
- cash is the availability of cash by SP
- land is the land (farming system's size) by hectare
- sprink is a dummy variable that takes the value of 1 if a sprinkler
  irrigation technique is present, 0 otherwise.
- drip is a dummy variable that takes the value of 1 if a drip
  irrigation technique is present, 0 otherwise.
- number is the number of farms represented by each farming system.
- agz defines the location of the farming system in different agro-ecological
  zones.
- river is a dummy variable that takes the value of 1 if the relevant farming
  system's water source is a river, 0 otherwise.
- net is a dummy variable that takes the value of 1 if the relevant farming
  system's water source is a public net, 0 otherwise.
- well is a dummy variable that takes the value of 1 if the relevant farming
  system's water source is a private well, 0 otherwise.
- cottonsls is a parameter related the cotton policy constraint, it represents
  the maximum area that can be cultivated under cotton by each farming system.
- autsugls is a parameter related the sugarbeet policy constraint, it represents
  the maximum area that can be cultivated under automn sugarbeet by each farming
  system.
- winsugls is a parameter related the sugarbeet policy constraint, it represents
  the maximum area that can be cultivated under winter sugarbeet by each farming
  system.
- barlreq is parameter related barley. It is based on a survey observation
  stating that farmers grow barley only to feed their sheep (not because it is
  profitable), so it represents the minimum area that must be cultivated under
  sheep to feed the livestock.
- rac is the risk aversion coefficient, and it was estimated by calibrating the
  model on different values for it, then we chose the one that gave the closest
  cropping mix to the observed one for each farm type.
$offtext

  irr irrigation techniques potentially available to each farming system
$ontext
There are four irrigation techniques: rainfed, flood (by gravity), sprinkler,
and drip moderm schemes. They were used as a criterion of technological
differences among farm types in the classification.
$offtext
 / rain
   flood
   sprink
   drip /
```

```
  wtr irrigation water sources
$ontext
There are three irrigatation water sources: rivers, public nets, and private
wells. They were used as a crietrion for technological differences among farm
types in the classification.
$offtext
 / riv
   net
   wel /

  t month
*Months of the year, many parameters are given by month
 / jan
   feb
   mar
   apr
   may
   jun
   jul
   aug
   sep
   oct
   nov
   dec /

* BEGIN CROP DATA
  c  the set of crops that are actually or eventually cultivated
$ontext
DEFINITIONS OF CROPS
wheat is winter wheat (winter crop)
barley is winter barley (winter crop)
intmaiz is intercalary maize (a summer crop)
lentil is winter lentil (winter crop)
chick is winter chickpea (winter crop)
bdbean is winter dry broad bean (a winter crop)
sybean is intercalary soybean (a summer crop)
autsugar is automn sugarbeet (a winter crop)
winsugar is winter sugarbeet (a winter crop)
sesame is intercalary sesame (a summer crop)
peanut is summer peanut (a summer crop)
cumin is winter cumin (winter crop)
cotton is summer cotton (a summer crop)
autmelon is automn watermelon (a summer crop)
summelon is summer watermelon (a summer crop)
sprptt is spring potato (a winter crop)
sumtmt is summer tomato (a summer crop)
sumegg is summer eggplant (a summer crop)

$offtext

 / wheat
   barley
   intmaiz
   lentil
   chick
   bdbean
   sybean
   autsugar
   winsugar
   sesame
   peanut
   cumin
   cotton
   autmelon
   summelon
   sprptt
   sumtmt
   sumegg   /

    cer(c) cereals
 / wheat
   barley /

$ontext
The following subset: exhcrop(c) represents the crops that cannot be grown in
the same landplot after harvesting cereal crops because they overlap with cereal
crops for their land requirements (see table landreq(c,t)). Most of them can be
considered soil exhausting, and so must be rotated with wheat or barley, and so
```

```
their total area must not exceed 50% total farm area (see equation rotation(t))
$offtext
  exhcrop(c) exhaustive crops that must be rotated every other year with cereals
  /lentil
   chick
   bdbean
   autsugar
   winsugar
   cumin
   peanut
   cotton
   sprptt /

  stracrop(c) the strategic crops that are covered by the credit system
  /wheat
   barley
   autsugar
   winsugar
   cotton /

  othercrop(c) the crops that are not covered by the credit system
 / intmaiz
   lentil
   chick
   bdbean
   sybean
   sesame
   peanut
   cumin
   autmelon
   summelon
   sprptt
   sumtmt
   sumegg   /

  sn the set of states of nature
  /1*10 /
$ontext
we used for convinience the assumption that farmers face ten states of nature
based on Gauss-Hermite quadrature (Numerical Methods in Economics: Kenneth &
Judd, 1998 Massachusetts Institute for Technology, the USA, Library of
Congress Cataloging-in-Publication Data.
$offtext

   p products: each product is composed of one crop or more
 / wheat
   barley
   maize
   lentil
   chickpea
   broadbean
   soybean
   sugarbeet
   sesame
   peanut
   cumin
   cotton
   wmelonsum
   wmelonaut
   potato
   tomato
   eggplant /

   in input
 / Nfert
   Pfert
   Kfert
   seed
   other  /
;

$INCLUDE C:\doctoral\Thesis\GAMS files\2-region-base.gms


* This set is just to allow repeating the set of products
alias (p,pp) ;
$ontext
these parameters and the following equations aim to allow:
```

```
1- the calculation of the mean prices of all products
2- the calculation of variance-covariance matrix of the prices of all products
3- the above two will allow us to calculate the total revenue variance of a
   farm type, which will be used in calculating the certainty equivalent which
   is the objective function to be maximised in our model.
$offtext

parameter
mean(p)      average prices of products
covar(p,pp)  variance-covariance matrix of prices of various products   ;

mean(p) = sum(sn, price(p,sn)*prob(sn)) ;
covar(p,pp) = sum(sn,(price(p,sn)-mean(p))*(price(pp,sn)-mean(pp))*prob(sn));

display mean, covar ;

* Here we define parameters which will be connected to their equivalents at the
* farm type level through the loop (see below)
parameter
  waterav(t)          irrigation water availability by month
  famlab(t)           family labour availability by month
  yyield(c,irr,p)     yields of different crops
  watereq(c,irr,t)    water requirements per month for different crops
  laboureq(c,irr,t)   labour requirements per month for different crops
  iinputs(in,c,irr)   physical inputs requirements for different crops
  diesel(c,irr,wtr)   diesel requirements for different crops
  rentals(c,irr,t)    rental machinery costs per month for different crops

* Here we define scalars which will be connected to their equivalents at the
* farm type level through the loop (see below)
scalar
  cash       availability of cash
  land       farm size per hectare
  sprink     zero if no sprink irrigation available on the relevant farm
  drip       zero if no drip irrigation available on the relevant farm
  river      if irrigation water source is a river
  punet      if irrigation water sources is public net
  pwell      if irrigation source is a private well
  cottonls   cotton licensing requirement
  autsugls   automn sugarbeet licensing requirement
  winsugls   winter sugarbeet licensing requirement
  barlreq    barley area required for sheep
  rac        the risk aversion coefficient
 ;

* here we define the model variables, the basic two variables are xcrop and hlab
* therefore, all other variables are dependent on them
Variables
           xcrop(c,irr,wtr) cropping activity                     (hectares)
           quantity(p)      quantity produced by product          (kg)
           revenue          Total average revenue                 (SP)
           labcost          labour cost                           (SP)
           hlab(t)          hired labour                          (hours)
           water            water consumption                     (cubic meter)
           labour           total labour employed                 (hour)
           hlabour          hired labour employed                 (hour)
           flabour          family labour used                    (hour)
           inputcost1       inputs variable costs for strategic   (SP)
           inputcost2       inputs variable costs for others      (SP)
           rentalcost1      rental machinery cost for strategic   (SP)
           rentalcost2      rental machinery cost for others      (SP)
           irrcost          the costs of pumping irrigation water  (SP)
           totcost          total variable costs                  (SP)
           totvariance      Total income variance                 (SP)
           grossmargin      gross margin                          (SP)
           certequiv        Certainty equivalent                  (SP)
;
* Here we define the variables that must be negative, they are the two basic
* variables
positive variables
           xcrop(c,irr,wtr)
           hlab(t) ;

* Here we define the equations, see below the meaning of everyone
equations   landbal(t)     land balance                     (hectares)
            rotation(t)    rotational requirement
            laborbal(t)    labour balance                   (hours)
            cashbal        cash balance                     (SP)
```

```
            watercon(t)    water constraint                  (cubic meter)
            irrigation1(t) modern irrigation constraint
            irrigation2(t) modern irrigation constraint
            source1(t)     irrigation source constraint
            source2(t)     irrigation source constraint
            source3(t)     irrigation source constraint
            cotlic         cotton licensing constraint       (hectares)
            suglic1        autsugarbeet licensing            (hectares)
            suglic2        winsugarbeet licensing            (hectares)
            barcon         barley area needed for sheep      (hectares)
            output(p)      quantity accounting by product    (kg)
            arev           average revenue accounting        (SP)
            inpcosts1      input cost accounting strategic   (SP)
            inpcosts2      input cost accounting others      (SP)
            diescost       diesel costs                      (SP)
            rentcost1      rental cost accounting strategic  (SP)
            rentcost2      rental cost accounting others     (SP)
            alab           labour cost accounting            (SP)
            wateruse       water use                         (cubic meter)
            laboruse       labour use                        (hour)
            hiredlab       hired labour employed             (hour)
            familylab      family labour used                (hour)
            cost           total costs accounting            (SP)
            totvar         total income variance accounting  (SP)
            GM             gross margin accounting           (SP)
            CE             certainty equivalent accounting   (SP)

;

* the equations are classified in three main groups
* the first includes the constraints equations
* the second includes the objective functions equations
* the third includes results equations

* the constraints equations

* land constraint: total cultivated area by month must not exceed the farm size
landbal(t)..  sum(wtr,sum(irr,sum(c, xcrop(c,irr,wtr)*landreq(c,t)))) =l= land ;

* the sum of exhaustive crops must not exceed 50% of the total land area of a
* farm type, that is to say the sum of cereal crops' areas must be 50% at least
rotation(t)..  sum(wtr,sum(irr,sum(exhcrop,xcrop(exhcrop,irr,wtr)*
                                     landreq(exhcrop,t)))) =l= 0.5*land ;

* the sum of total labour used in by month must not exceed the available family
* labour plus hired labour in the same month
laborbal(t)..  sum(wtr,sum(c, sum(irr, xcrop(c,irr,wtr)*laboureq(c,irr,t))))=l=
                                                          famlab(t) + hlab(t)  ;

* the sum of irrigation water used by month must not exceed the available water
* in the same month
watercon(t)..  sum(wtr,sum(c,sum(irr, xcrop(c,irr,wtr)*watereq(c,irr,t))))
                                                                =l= waterav(t) ;

* the sum of costs times the corresponding coefficient of cash anticipation must
* not exceed the availbility of cash at the beginning of the agricultural year
* for each farm type
cashbal..    sum(c, sum(in,sum(irr,sum(wtr, alpha(c)*xcrop(c,irr,wtr)*
                    (iinputs(in,c,irr)*priceinp(in,c)))))) +
             sum(t,sum(c,sum(irr,sum(wtr,alpha(c)*xcrop(c,irr,wtr)*
                    rentals(c,irr,t)))))+ sum(c,sum(irr,sum(wtr, beta(c)*
                    xcrop(c,irr,wtr)*diesel(c,irr,wtr)*dies)))
                                         + sum(t,hlab(t)*hwage) =l= cash;
$ontext
For simplicity, we assume here that the costs of hired labour cannot be covered
by the credit system. This is justified by the fact that short-term credit is
always provided on a crop basis, while hired labour is determined in our model
on a month basis regardless of the crop for which it will be used.
$offtext

* the following five equations aim at allowing GAMS to read the dummy variables

* this is for the dummy of sprinkler irrigation
irrigation1(t)..  sum(c, sum(wtr,xcrop(c,"sprink",wtr)*landreq(c,t))) =l=
                                                                  sprink*land ;

* this is for the dummy of drip irrigation
irrigation2(t)..  sum(c,sum(wtr, xcrop(c,"drip",wtr)*landreq(c,t))) =l=
```

```
                                                                   drip*land ;

* this is for the dummy of river water source
source1(t)..      sum(c,sum(irr,xcrop(c,irr,"riv")*landreq(c,t))) =l=
                                                                  river*land ;

* this is for the dummy of public net water source
source2(t)..      sum(c,sum(irr,xcrop(c,irr,"net")*landreq(c,t))) =l=
                                                                  punet*land ;

* this is for the dummy of private well water source
source3(t)..      sum(c,sum(irr,xcrop(c,irr,"wel")*landreq(c,t))) =l=
                                                                  pwell*land ;

* the following three equations are policy constraints representing licensing
* systems for various crops

* this is for cotton
cotlic..      sum(wtr,sum(irr, xcrop("cotton",irr,wtr))) =l= cottonls ;

* this is for automn sugarbeet
suglic1..     sum(wtr,sum(irr, xcrop("autsugar",irr,wtr))) =l= autsugls ;

* this is for winter sugarbeet
suglic2..     sum(wtr,sum(irr, xcrop("winsugar",irr,wtr))) =l= winsugls ;

* this constraint represents the problem of irrigated barley that is grown for
* feeding the sheep
barcon..      sum(wtr,sum(irr, xcrop("barley",irr,wtr))) =g= barlreq ;

* accounting equations to form the elements of the objective function

* this equation is to calculate the quantity produced by product
output(p)..    quantity(p) =e= sum(c,sum(irr,sum(wtr,xcrop(c,irr,wtr)*
                                                          yyield(c,irr,p))));

* this is to calculate the total revenue taken into account price variation
* and probability parameter
arev..         revenue =e= sum(p,quantity(p)*mean(p)) ;

* this is to calucalate physical input costs (fertilizers, seeds and others)
* for crops covered by the credit system
inpcosts1..    inputcost1 =e= sum(stracrop, sum(in, sum(irr,sum(wtr,
                              xcrop(stracrop,irr,wtr)* iinputs(in,stracrop,irr))
                              *priceinp(in,stracrop)*(1 + intrate))));

* this is to calucalate physical input costs (fertilizers, seeds and others)
* for crops NOT covered by the credit system
inpcosts2..    inputcost2 =e= sum(othercrop,sum(in,sum(irr,sum(wtr,
                                    xcrop(othercrop,irr,wtr)* iinputs(in,
                                    othercrop,irr))*priceinp(in,othercrop))));

* this is to calculate pumping costs (diesel)
diescost..     irrcost =e= sum(wtr,sum(c,sum(irr, xcrop(c,irr,wtr)*
                                                     diesel(c,irr,wtr)*dies))) ;

* this is to calculate the costs of renting machinery for crops covered by the
* credit system
rentcost1..     rentalcost1 =e= sum(t, sum(irr, sum(wtr,sum(stracrop,
                                xcrop(stracrop,irr,wtr)*rentals(stracrop,irr,t)
                                *(1 + intrate)))));
* this is to calculate the costs of renting machinery for crops NOT covered by
* the credit system
rentcost2..    rentalcost2 =e= sum(t,sum(irr,sum(wtr,sum(othercrop,
                                                     xcrop(othercrop,irr,wtr)*
                                                   rentals(othercrop,irr,t)))));

* this is to calculate the cost of hired labour
alab..         labcost =e= sum(t, hlab(t)*hwage);

* this is to calculate total costs
cost..         totcost =e= inputcost1 + inputcost2 + irrcost + rentalcost1 +
                            rentalcost2 + labcost + waterfee*land*punet ;

* this is to calculate the variance of the total farm revenue
totvar..       totvariance =e= (sum(pp,sum(p,quantity(pp)*
                                                    covar(p,pp)*quantity(p)))) ;
```

```
* this is to calculate the total gross margin
GM..           grossmargin =e= revenue - totcost  ;


* this is the objective function: it is the certainty equivalent
CE..           certequiv =e= grossmargin - 0.5*rac*totvariance ;

* these equations are to calculate some outputs of the model

* this equation is to calculate irrigation water use
wateruse..     water =e= sum(t,sum(c,sum(irr,sum(wtr, xcrop(c,irr,wtr)*
                                                      watereq(c,irr,t)))));

* this equation is to calculate total labour use
laboruse..     labour =e= sum(t,sum(c,sum(irr,sum(wtr,xcrop(c,irr,wtr)*
                                                     laboureq(c,irr,t)))));

* this equation is to calculate hired labour employed
hiredlab..     hlabour =e= sum(t, hlab(t)) ;

* this equation is to calculate family labour used
familylab..    flabour =e= labour - hlabour ;


$INCLUDE C:\doctoral\Thesis\GAMS files\3-mantikas-base.gms
$INCLUDE C:\doctoral\Thesis\GAMS files\4-farms-base.gms

 Model farmrev farm model /all/    ;

* THESE PARAMETERS ARE FOR REPORTING ONLY
parameter
          supply(p,rr,i)            outputs by product and mantika (ton)
          area(c,irr,wtr,rr,i)      areas of crops at mantika level (ha)

          waterconsumption(rr,i)    water use by mantika (million CM)
          agriemployment(rr,i)      total labour use by mantika (thousand h)
          hiredemployment(rr,i)     hired labour use by mantika (thousand h)
          netrevenue(rr,i)          GM at mantika level (million SP)
          grossutility(rr,i)        CE at the mantika level (million SP)
          areaM(rr,i)               cropping area at mantika level (thousand ha)

* these two parameters are useful for validation and calibration
          report(i,rr,fff,wtr,c,irr) cropping patterns at the farm level
          imbalance(i,rr,fff,wtr,c,irr)
* CE means certainty equivalent
* GM means gross margin
* FL means family labour
* TL means total labour
* TW means total water use
* SP means syrian pound
* ha means hectare
* h means working hour
* CM means cubic meter

          exputility(rr,fff,i)    CE at farm level (SP)
          grossmargins(rr,fff,i)  GM at farm level (SP)

          exputHa(rr,fff,i)       CE by hectare at farm level (SP per ha)
          grossmHa(rr,fff,i)      GM by hectare at farm level (SP per ha)

          famlabour(rr,fff,i)     FL used at farm level (h)
          exputLabF(rr,fff,i)     CE by unit of FL at farm level (SP per h)
          grossmLabF(rr,fff,i)    GM by unit of FL at farm level (SP per h)

          totlabour(rr,fff,i)     TL employed at farm level (h)
          exputLabT(rr,fff,i)     CE by unit of TL at farm level (SP per h)
          grossmLabT(rr,fff,i)    GM by unit of TL at farm level (SP per h)

          totwater(rr,fff,i)      TW used at farm level (CM)
          exputWat(rr,fff,i)      CE by unit of TW at farm level (SP per CM)
          grossmWat(rr,fff,i)     GM by unit of TW at farm level (SP per CM)

          exputHaM(rr,i)          CE by hectare at mantika level (SP per ha)
          grossmHaM(rr,i)         GM by hectare at mantika level (SP per ha)

          exputLabFM(rr,i)        CE by unit of FL at mantika level (SP per h)
          grossmLabFM(rr,i)       GM by unit of FL at mantika level (SP per h)
```

```
        exputLabTM(rr,i)        CE by unit of TL at mantika level (SP per h)
        grossmLabTM(rr,i)       GM by unit of TL at mantika level (SP per h)

        exputWatM(rr,i)         CE by unit of TW at mantika level (SP per CM)
        grossmWatM(rr,i)        GM by unit of TW at manitka level (SP per CM)

        report1(p,i,*)          outputs by product by governorate (ton)
        report2(c,i,*)          areas of crops by governorate (ha)
        report12(i,*)           total cropping area ny governorate (ha)
        report3(i,*)            water use by basin (million CM)
        report4(i,*)            labour use by governorate (thousand h)
        report5(i,*)            hired labour use by governorate (thousand h)
        report6(i,*)            GM by governorate (million SP)
        report7(i,*)            CE by governorate (million SP)

        report8(i,*)            GM per hectare by gov (SP per ha)
        report9(i,*)            GM per unit of family labour by gov (SP per h)
        report10(i,*)           GM per unit of total labour by gov (SP per h)
        report11(i,*)           GM per unit of water used by gov (SP per CM)

   ;


supply(p,rr,i) = 0  ;
waterconsumption(rr,i) = 0;
agriemployment(rr,i) = 0 ;
hiredemployment(rr,i) = 0 ;
netrevenue(rr,i)= 0 ;
grossutility(rr,i) = 0 ;
areaM(rr,i) = 0 ;
area(c,irr,wtr,rr,i) = 0 ;

set
    rrr(rr)    mantikas solved in the loop               /1*10 /
    ffff(fff)  farms solved in the loop                  /1*15 /

set
    has(rrr)   Mantikas of Al-Hassakeh                   /1*4/
    rak(rrr)   Mantikas of Al-Rakka                      /5*7 /
    der(rrr)   Mantikas of Deir-Ezzour                   /8*10/

  ;

Loop(i,
supply(p,rrr,i) = 0 ;
waterconsumption(rrr,i) = 0 ;
agriemployment(rrr,i) = 0 ;
hiredemployment(rrr,i) = 0 ;
netrevenue(rrr,i) = 0 ;
areaM (rrr,i) = 0 ;
area(c,irr,wtr,rrr,i) = 0 ;
 Loop(rrr,
  Loop(ffff,
* Here is the initialization of model scalars according to each farm type
   cash = farm(rrr,ffff,"cash");
   land = farm(rrr,ffff,"land");
   sprink = farm(rrr,ffff,"sprink");
   drip = farm(rrr,ffff,"drip");
   river = farm(rrr,ffff,"river");
   punet = farm(rrr,ffff,"punet");
   pwell = farm(rrr,ffff,"pwell") ;
   cottonls = farm(rrr,ffff,"cottonls") ;
   autsugls = farm(rrr,ffff,"autsugls") ;
   winsugls = farm(rrr,ffff,"winsugls") ;
   barlreq = farm(rrr,ffff,"barlreq") ;
   rac = farm(rrr,ffff,"rac") ;
* Here is the initialization of model parameters according to each farm type
   waterav(t) = wateravail(rrr,ffff,t);
   famlab(t) = famlabav(rrr,ffff,t);
* Here is the inilialization of model parameters according to mantika and
* agro-ecological zone
   yyield(c,irr,p)$(farm(rrr,ffff,"agz")=1) = yield(rrr,c,p,irr,"1");
   yyield(c,irr,p)$(farm(rrr,ffff,"agz")=2) = yield(rrr,c,p,irr,"2");
   yyield(c,irr,p)$(farm(rrr,ffff,"agz")=3) = yield(rrr,c,p,irr,"3");
   yyield(c,irr,p)$(farm(rrr,ffff,"agz")=4) = yield(rrr,c,p,irr,"4");
   yyield(c,irr,p)$(farm(rrr,ffff,"agz")=5) = yield(rrr,c,p,irr,"5");

   watereq(c,irr,t)$(farm(rrr,ffff,"agz")=1) = waterreq(rrr,"1",c,irr,t);
```

```
   watereq(c,irr,t)$(farm(rrr,ffff,"agz")=2) = waterreq(rrr,"2",c,irr,t);
   watereq(c,irr,t)$(farm(rrr,ffff,"agz")=3) = waterreq(rrr,"3",c,irr,t);
   watereq(c,irr,t)$(farm(rrr,ffff,"agz")=4) = waterreq(rrr,"4",c,irr,t);
   watereq(c,irr,t)$(farm(rrr,ffff,"agz")=5) = waterreq(rrr,"5",c,irr,t);

   laboureq(c,irr,t)$(farm(rrr,ffff,"agz")=1) = labourreq(rrr,"1",c,irr,t);
   laboureq(c,irr,t)$(farm(rrr,ffff,"agz")=2) = labourreq(rrr,"2",c,irr,t);
   laboureq(c,irr,t)$(farm(rrr,ffff,"agz")=3) = labourreq(rrr,"3",c,irr,t);
   laboureq(c,irr,t)$(farm(rrr,ffff,"agz")=4) = labourreq(rrr,"4",c,irr,t);
   laboureq(c,irr,t)$(farm(rrr,ffff,"agz")=5) = labourreq(rrr,"5",c,irr,t);

   iinputs(in,c,irr)$(farm(rrr,ffff,"agz")=1) = input(rrr,"1",in,c,irr);
   iinputs(in,c,irr)$(farm(rrr,ffff,"agz")=2) = input(rrr,"2",in,c,irr);
   iinputs(in,c,irr)$(farm(rrr,ffff,"agz")=3) = input(rrr,"3",in,c,irr);
   iinputs(in,c,irr)$(farm(rrr,ffff,"agz")=4) = input(rrr,"4",in,c,irr);
   iinputs(in,c,irr)$(farm(rrr,ffff,"agz")=5) = input(rrr,"5",in,c,irr);

   rentals(c,irr,t)$(farm(rrr,ffff,"agz")=1) = rentalmachcost(rrr,"1",c,irr,t);
   rentals(c,irr,t)$(farm(rrr,ffff,"agz")=2) = rentalmachcost(rrr,"2",c,irr,t);
   rentals(c,irr,t)$(farm(rrr,ffff,"agz")=3) = rentalmachcost(rrr,"3",c,irr,t);
   rentals(c,irr,t)$(farm(rrr,ffff,"agz")=4) = rentalmachcost(rrr,"4",c,irr,t);
   rentals(c,irr,t)$(farm(rrr,ffff,"agz")=5) = rentalmachcost(rrr,"5",c,irr,t);

   diesel(c,irr,wtr)$(farm(rrr,ffff,"agz")=1)= dieselreq(rrr,c,irr,wtr,"1");
   diesel(c,irr,wtr)$(farm(rrr,ffff,"agz")=2)= dieselreq(rrr,c,irr,wtr,"2");
   diesel(c,irr,wtr)$(farm(rrr,ffff,"agz")=3)= dieselreq(rrr,c,irr,wtr,"3");
   diesel(c,irr,wtr)$(farm(rrr,ffff,"agz")=4)= dieselreq(rrr,c,irr,wtr,"4");
   diesel(c,irr,wtr)$(farm(rrr,ffff,"agz")=5)= dieselreq(rrr,c,irr,wtr,"5");


   solve farmrev  using nlp maximizing certequiv ;

*calculate the areas of different crops by farm (unit: ha)
   report(i,rrr,ffff,wtr,c,irr) = xcrop.l(c,irr,wtr) ;

*caculate certainty equivalents by farm (unit: SP)
   exputility(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = certequiv.l ;

*calculate gross margins by farm (unit: SP)
   grossmargins(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = grossmargin.l ;

*calculate certainty equivalent by hectere (unit: SP/ha)
   exputHa(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) =
                                        certequiv.l/farm(rrr,ffff,"land")  ;

*calculate gross margin by hectere (unit: SP/ha)
   grossmHa(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) =
                                       grossmargin.l/farm(rrr,ffff,"land") ;

*calculate family labour used by farm (unit: hour)
  famlabour(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = flabour.l ;

*calculate certainty equivalent by unit of family labour (unit: SP/hour)
  exputLabF(rrr,ffff,i)$ (farm(rrr,ffff,"land")gt 0) = certequiv.l/flabour.l ;

*calculate gross margins by unit of family labour (unit: SP/hour)
  grossmLabF(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = grossmargin.l/flabour.l ;

*calculate total labour used by farm (unit: hour)
  totlabour(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = labour.l ;

*calculate certainty equivalent by unit of labour (unit: SP/hour)
  exputLabT(rrr,ffff,i)$ (farm(rrr,ffff,"land")gt 0) = certequiv.l/labour.l ;

*calculate gross margins by unit of family labour (unit: SP/hour)
  grossmLabT(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = grossmargin.l/labour.l ;

*calculate water used by farm (unit: cubic meter)
  totwater(rrr,ffff,i)$(farm(rrr,ffff,"land")gt 0) = water.l ;

*calculate certainty equivalent by unit of water used (unit: SP/cubic meter)
  exputWat(rrr,ffff,i)$(farm(rrr,ffff,"land") gt 0) = certequiv.l/water.l ;

*calculate gross margin by unit of water used (unit: SP/cubic meter)
  grossmWat(rrr,ffff,i)$(farm(rrr,ffff,"land") gt 0) = grossmargin.l/water.l ;

*calculate the regions' aggregate supply (unit:ton)
   supply(p,rrr,i) = supply(p,rrr,i) + farm(rrr,ffff,"number")*
```

```
             sum(c, sum(irr,sum(wtr, xcrop.l(c,irr,wtr)*yyield(c,irr,p))))/1000;

*Calculate the cropping areas by crop and mantika (unit: ha)
   area(c,irr,wtr,rrr,i) = area(c,irr,wtr,rrr,i) +
                                farm(rrr,ffff,"number")*xcrop.l(c,irr,wtr);

*calculate total cropping area at mantika level (unit: ha)
   areaM(rrr,i) = areaM(rrr,i) + farm(rrr,ffff,"number")*
                             sum(c,sum(irr,sum(wtr, xcrop.l(c,irr,wtr)))) ;

*calculate the mantikas' aggregate water use (unit: cubic meters)
   waterconsumption(rrr,i) = waterconsumption(rrr,i) +
                                     farm(rrr,ffff,"number")*water.l;

*calculate the aggregate agricultural employment (unit: hour)
   agriemployment(rrr,i) = agriemployment(rrr,i) +
                                      farm(rrr,ffff,"number")*labour.l ;

*calculate the aggregate hired casual agricultural labour (unit: hour)
   hiredemployment(rrr,i) = hiredemployment(rrr,i) +
                                     farm(rrr,ffff,"number")*hlabour.l ;

*calculate the gross margins at mantika level (unit: SP)
   netrevenue(rrr,i) = netrevenue(rrr,i) +
                                 farm(rrr,ffff,"number")*grossmargin.l ;

*calculate the certainty equivalents at mantika level (unit: SP)
   grossutility(rrr,i) = grossutility(rrr,i) + farm(rrr,ffff,"number")
                                                        *certequiv.l ;

*calculate the CE by hectare at mantika level (SP/ha)
   exputHaM(rrr,i) = grossutility(rrr,i)/(areaM(rrr,i));

*calculate the GM by hectare at mantika level (SP/ha)
   grossmHaM(rrr,i) = netrevenue(rrr,i)/(areaM(rrr,i));

*calculate CE by unit of FL at mantika level (SP/hour)
   exputLabFM(rrr,i) = grossutility(rrr,i)/((agriemployment(rrr,i) -
                                 hiredemployment(rrr,i))) ;

*calculate GM by unit of FL at mantika level (SP/hour)
   grossmLabFM(rrr,i) = netrevenue(rrr,i)/((agriemployment(rrr,i) -
                                 hiredemployment(rrr,i))) ;

*calculate CE by unit of TL at mantika level (SP/hour)
   exputLabTM(rrr,i) = grossutility(rrr,i)/(agriemployment(rrr,i)) ;

*calculate GM by unit of TL at mantika level (SP/hour)
   grossmLabTM(rrr,i) = netrevenue(rrr,i)/(agriemployment(rrr,i)) ;

*calculate CE by unit of TW at mantika level (SP/cubic meter)
   exputWatM(rrr,i) = grossutility(rrr,i)/waterconsumption(rrr,i) ;

*calculate GM by unit of TW at mantika level (SP/cubic meter)
   grossmWaTM(rrr,i) = netrevenue(rrr,i)/waterconsumption(rrr,i) ;

 );
);

report1(p,i,"output") = sum(rrr,supply(p,rrr,i));
report1(p,i,"outputHas") = sum(has,supply(p,has,i)) ;
report1(p,i,"outputRak") = sum(rak,supply(p,rak,i)) ;
report1(p,i,"outputDer") = sum(der,supply(p,der,i));

report2(c,i,"croparea") = sum(irr,sum(wtr,sum(rrr,area(c,irr,wtr,rrr,i))));
report2(c,i,"cropareaHas") = sum(irr,sum(wtr,sum(has,area(c,irr,wtr,has,i))));
report2(c,i,"cropareaRak") = sum(irr,sum(wtr,sum(rak,area(c,irr,wtr,rak,i))));
report2(c,i,"cropareaDer") = sum(irr,sum(wtr,sum(der,area(c,irr,wtr,der,i))));

report12(i,"cropping")=sum(c,sum(irr,sum(wtr,sum(rrr,area(c,irr,wtr,rrr,i))))) ;
report12(i,"cropping1")=sum(c,sum(irr,sum(wtr,sum(has,area(c,irr,wtr,has,i)))));
report12(i,"cropping2")=sum(c,sum(irr,sum(wtr,sum(rak,area(c,irr,wtr,rak,i)))));
report12(i,"cropping3")=sum(c,sum(irr,sum(wtr,sum(der,area(c,irr,wtr,der,i)))));

report3(i,"wateruse") = sum(rrr,waterconsumption(rrr,i))/1000000 ;
report3(i,"waterHas") = sum(has,waterconsumption(has,i))/1000000 ;
report3(i,"waterRak") = sum(rak,waterconsumption(rak,i))/1000000 ;
report3(i,"waterDer") = sum(der,waterconsumption(der,i))/1000000 ;
```

```
report4(i,"labouruse") = sum(rrr,agriemployment(rrr,i))/1000;
report4(i,"labHas") = sum(has,agriemployment(has,i))/1000;
report4(i,"labRak") = sum(rak,agriemployment(rak,i))/1000;
report4(i,"labDer") = sum(der,agriemployment(der,i))/1000;

report5(i,"hiredlab") = sum(rrr,hiredemployment(rrr,i))/1000;
report5(i,"hiredlabHas") =  sum(has,hiredemployment(has,i))/1000;
report5(i,"hiredlabRak") =  sum(rak,hiredemployment(rak,i))/1000;
report5(i,"hiredlabDer") =  sum(der,hiredemployment(der,i))/1000;

report6(i,"GM") = sum(rrr,netrevenue(rrr,i))/1000000 ;
report6(i,"GMHas") = sum(has,netrevenue(has,i))/1000000 ;
report6(i,"GMRak") = sum(rak,netrevenue(rak,i))/1000000 ;
report6(i,"GMDer") = sum(der,netrevenue(der,i))/1000000 ;

report7(i,"utility") = sum(rrr,grossutility(rrr,i))/1000000 ;
report7(i,"utilityHas") = sum(has,grossutility(has,i))/1000000 ;
report7(i,"utilityRak") = sum(rak,grossutility(rak,i))/1000000 ;
report7(i,"utilityDer") = sum(der,grossutility(der,i))/1000000 ;

report8(i,"GMperHA") = sum(rrr,netrevenue(rrr,i))/sum(rrr,sum(ffff,farm
                                   (rrr,ffff,"number")*farm(rrr,ffff,"land")));
report8(i,"GMperHA1") = sum(has,netrevenue(has,i))/sum(has,sum(ffff,farm
                                   (has,ffff,"number")*farm(has,ffff,"land")));
report8(i,"GMperHA2") = sum(rak,netrevenue(rak,i))/sum(rak,sum(ffff,farm
                                   (rak,ffff,"number")*farm(rak,ffff,"land")));
report8(i,"GMperHA3") = sum(der,netrevenue(der,i))/sum(der,sum(ffff,farm
                                   (der,ffff,"number")*farm(der,ffff,"land"))) ;

report9(i,"GMperFL")=sum(rrr,netrevenue(rrr,i))/(sum(rrr,agriemployment(rrr,i))
                                             - sum(rrr,hiredemployment(rrr,i)));
report9(i,"GMperFL1")=sum(has,netrevenue(has,i))/(sum(has,agriemployment(has,i))
                                             - sum(has,hiredemployment(has,i)));
report9(i,"GMperFL2")=sum(rak,netrevenue(rak,i))/(sum(rak,agriemployment(rak,i))
                                             - sum(rak,hiredemployment(rak,i)));
report9(i,"GMperFL3")=sum(der,netrevenue(der,i))/(sum(der,agriemployment(der,i))
                                             - sum(der,hiredemployment(der,i)));

report10(i,"GMperTL")=sum(rrr,netrevenue(rrr,i))/sum(rrr,agriemployment(rrr,i));
report10(i,"GMperTL1")=sum(has,netrevenue(has,i))/sum(has,agriemployment(has,i));
report10(i,"GMperTL2")=sum(rak,netrevenue(rak,i))/sum(rak,agriemployment(rak,i));
report10(i,"GMperTL3")=sum(der,netrevenue(der,i))/sum(der,agriemployment(der,i));

report11(i,"GMperTL")=sum(rrr,netrevenue(rrr,i))/sum(rrr,waterconsumption(rrr,i));
report11(i,"GMperTL1")=sum(has,netrevenue(has,i))/sum(has,waterconsumption(has,i));
report11(i,"GMperTL2")=sum(rak,netrevenue(rak,i))/sum(rak,waterconsumption(rak,i));
report11(i,"GMperTL3")=sum(der,netrevenue(der,i))/sum(der,waterconsumption(der,i));

);

imbalance(i,rrr,ffff,wtr,c,irr) = observed(rrr,ffff,wtr,c,irr)-
                                                  report(i,rrr,ffff,wtr,c,irr);

* these two reports are useful for validation and calibration:
* "report" shows the areas of crops according by farm and irrigation technique
*option report:2:3:2;display report
*"imbalance" shows the differences between the areas given by the solution and
* the abserved ones.
*option imbalance:2:3:2;display imbalance

* the areas of crops at governorate level
option report2:2;display report2

* total cropping area at governorate level
option report12:2;display report12

* water use at basin level
option report3:2;display report3

* total agricultural labour use at governorate level
option report4:2;display report4

* hired agricultural labour at governorate level
option report5:2;display report5

* gross margin at governorate level
option report6:2;display report6
```

```
* certainty equivalent at governorate level
option report7:2;display report7

* GM per ha at the governorate level
option report8:2;display report8

* GM per unit of famil labour at governorate level
option report9:2;display report9

* GM per unit of total labour at governorate level
option report10:2;display report10

* GM per unit of water use at governorate level
option report11:2;display report11
```

I.2. data of parameters applied to all farm typologies

I.2.1. Coefficients of cash anticipation

```
parameter alpha(c) coefficient of cash anticipation of inputs covered by the credit system
$ontext
This parameter has been made to represent credit policy that favours strategic crops. These
parameters are going to be used in the cash constraints equations.
The parameters will be used with costs that are covered by the credit system
As clear, crops that receive credit from the credit system have a coefficient
of zero, while these not covered have coefficient greater than zero. The
coefficient represents the proportion period of the crop's stay in land with
respect to the entire year.
Credit system covers costs of fertilizers and seeds for cotton, sugarbeet, wheat
and barley.
In addition, there are some costs that have no cash problem due to other sources
of credit. For example, the cost of machinery used in harvesting wheat and
barley is covered by the fact that it is either paid in kind (as a proportion of
the output) or it is paid later (after farmers get the revenue of their output)
Another example is the harvest of cotton in which farmers manage to postpone the
payments until they have received the payments.
$offtext
/ wheat       0.00
  barley      0.00
  intmaiz     0.38
  lentil      0.54
  chick       0.54
  bdbean      0.54
  sybean      0.33
  autsugar    0.00
  winsugar    0.00
  sesame      0.29
  peanut      0.46
  cumin       0.54
  cotton      0.00
  autmelon    0.33
  summelon    0.29
  sprptt      0.50
  sumtmt      0.29
  sumegg      0.29        /
        ;

parameter beta(c)  coefficient of cash anticipation of inputs not covered by the credit system
$ontext
This coefficient instead will be used in cash constraints for costs of inputs
that are not covered by the credit sources (whether the formal credit system or
the informal credit sources) for all crops. In other words, they will be used
with all costs that require cash money to be covered. That is why they all
have values greater than zero.
$offtext

/ wheat        0.67
  barley       0.63
  intmaiz      0.38
  lentil       0.54
  chick        0.54
  bdbean       0.54
  sybean       0.33
  autsugar     0.83
  winsugar     0.63
  sesame       0.29
```

```
  peanut        0.46
  cumin         0.54
  cotton        0.71
  autmelon      0.33
  summelon      0.29
  sprptt        0.50
  sumtmt        0.29
  sumegg        0.29       /
;
```

I.2.2. crops' requirements of land by month

```
* autmelon overlaps with barley in October. this may have to be revised since autmelon may be
* considered intercalary crops
table landreq(c,t)        land occupation of crops by month
            jan    feb    mar    apr    may     jun     jul     aug     sep     oct     nov     dec
wheat       1      1      1      1      1       0.5     0       0       0       0       1       1
barley      1      1      1      1      0.5     0       0       0       0       0.5     1       1
intmaiz     0      0      0      0      0       0.5     1       1       1       0.5     0       0
lentil      1      1      1      1      1       0.5     0       0       0       0       0       0.5
chick       1      1      1      1      1       0.5     0       0       0       0       0       0.5
bdbean      1      1      1      1      1       1       0       0       0       0       0       0
sybean      0      0      0      0      0       0.5     1       1       1       0       0       0
autsugar    1      1      1      1      1       1       0.5     0       0       1       1       1
winsugar    1      1      1      1      1       1       1       0       0       0       0       0
sesame      0      0      0      0      0       0       1       1       1       0       0       0
peanut      0      0.5    1      1      1       1       0.5     0       0       0       0       0
cumin       1      1      1      1      1       0.5     0       0       0       0       0       0.5
cotton      0      0      0      1      1       1       1       1       1       1       1       0
autmelon    0      0      0      0      0       0       1       1       1       0.5     0       0
summelon    0      0      0      0      0       0.5     1       1       0.5     0       0       0
sprptt      0      1      1      1      1       1       0.5     0       0       0       0       0
sumtmt      0      0      0      0      0       0.5     1       1       0.5     0       0       0
sumegg      0      0      0      0      0       0.5     1       1       0.5     0       0       0
;
```

I.2.3 – matrix of prices assuming lognormal distribution

```
Table price(p,sn) prices of various products in different states of nature
$ontext
re assumed to be lognormally distributed. This is because prices cannot collapse
to zero, even when the supply is too high due to the existence of the possibility
of storage. On the other hand, prices can go very high if the supply is too low
and there is nothing can stop it. This in total justifies the choice of this
distribution which has the form of an asymetric bell skewed very much to the
right, in which the skewness increases more for commodities that are less storable
$offtext
```

	1	2	3	4	5	6	7	8	9	10
wheat	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50
barley	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
maize	6.83	7.54	8.22	8.90	9.60	10.36	11.18	12.11	13.19	14.57
lentil	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00	22.00
chickpea	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00	24.00
broadbean	18.30	20.18	21.95	23.73	25.58	27.55	29.69	32.10	34.91	38.49
soybean	14.24	15.57	16.81	18.05	19.33	20.69	22.16	23.79	25.69	28.09
sugarbeet	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
sesame	18.77	22.11	25.45	29.00	32.89	37.25	42.24	48.13	55.40	65.26
peanut	14.22	16.50	18.74	21.09	23.63	26.45	29.64	33.36	37.89	43.94
cumin	25.08	30.00	35.00	40.37	46.33	53.08	60.91	70.27	81.97	98.06
cotton	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00
wmelonsum	1.44	1.74	2.04	2.37	2.74	3.17	3.66	4.26	5.01	6.05
wmelonaut	1.59	1.95	2.33	2.75	3.22	3.76	4.41	5.19	6.20	7.61
potato	1.84	2.49	3.23	4.12	5.20	6.55	8.27	10.54	13.69	18.55
tomato	1.46	1.92	2.42	3.00	3.69	4.54	5.58	6.93	8.74	11.46
eggplant	2.18	2.71	3.27	3.89	4.59	5.42	6.41	7.63	9.20	11.44

```
;
```

I.2.4. probabilities associated to states of nature of price distribution

```
Parameter prob(sn) probability of each state of nature for prices (they sum up to one)

/ 1    0.0000043107
  2    0.0007580709
  3    0.0191115805
  4    0.1354837029
  5    0.3446423349
  6    0.3446423349
  7    0.1354837029
  8    0.0191115805
  9    0.0007580709
  10   0.0000043107     /
;
```

I.2.5. prices of physical inputs and other costs (SP/kg)

```
parameter priceinp(in,c) prices of various inputs: chemical fertilizers - seeds and others (SP per
KG)  ;
priceinp("Nfert",c)        =        7.70       ;
priceinp("Pfert",c)        =        8.30       ;
priceinp("Kfert",c)        =       12.10       ;
priceinp("seed","wheat")   =       15.00       ;
priceinp("seed","barley")  =       13.00       ;
priceinp("seed","intmaiz") =       22.00       ;
priceinp("seed","lentil")  =       55.00       ;
priceinp("seed","chick")   =       60.00       ;
priceinp("seed","bdbean")  =       30.00       ;
priceinp("seed","sybean")  =       20.00       ;
priceinp("seed","autsugar")=      430.00       ;
priceinp("seed","winsugar")=      430.00       ;
priceinp("seed","sesame")  =       50.00       ;
priceinp("seed","peanut")  =       60.00       ;
priceinp("seed","cumin")   =      150.00       ;
priceinp("seed","cotton")  =       11.00       ;
priceinp("seed","autmelon")=      100.00       ;
priceinp("seed","summelon")=      100.00       ;
priceinp("seed","sprptt")  =       30.00       ;
priceinp("seed","sumtmt")  =     1000.00       ;
priceinp("seed","sumegg")  =     1000.00       ;
priceinp("other",c)        =        1.00       ;


scalar hwage     hired labour wage (SP per Hour)                  / 25 /     ;
scalar waterfee  irrigation water fee for public net (SP per ha)  /650/     ;
scalar dies      price of diesel                                  / 8 /      ;
scalar intrate   interest rate of the credit                      /0.06/ ;
```

I.3. data of parameters differentiated by mantikas and agro-climatic zones

I.3.1. yields of crops (kg/ha)

```
table yield(rr,c,p,irr,agz)
* yields of different crops given by mantika, crop, product, irrigation method and agro-climatic
* zone (kg/ha)
                                    1        2        3        4        5
1.wheat.wheat.flood               3730     3560     3830     3550     3710
2.wheat.wheat.flood               3610     4030     3680
3.wheat.wheat.flood               4130     4070     3700
4.wheat.wheat.flood               4020     3830     3830     3670
1.wheat.wheat.sprink              4103     3916     4213     3905     4081
2.wheat.wheat.sprink              3971     4433     4048
3.wheat.wheat.sprink              4543     4477     4070
4.wheat.wheat.sprink              4422     4213     4213     4037
1.wheat.wheat.rain                1434     1102     524      424      304
2.wheat.wheat.rain                1478     1016     796
3.wheat.wheat.rain                2180     1874     1332
4.wheat.wheat.rain                1372     902      504      232
5.wheat.wheat.flood                 0        0      4528     4730     5194
6.wheat.wheat.flood                 0        0      4996     4518     4400
7.wheat.wheat.flood                 0      4350     4008     3470       0
5.wheat.wheat.sprink                0        0      4981     5203     5713
6.wheat.wheat.sprink                0        0      5496     4970     4840
7.wheat.wheat.sprink                0      4785     4409     3817       0
5.wheat.wheat.rain                  0        0      402      394       20
```

6.wheat.wheat.rain	0	0	880	450	20
7.wheat.wheat.rain	0	1286	608	40	0
8.wheat.wheat.flood	0	0	0	0	5000
9.wheat.wheat.flood	0	0	0	0	4000
10.wheat.wheat.flood	0	0	0	0	4200
8.wheat.wheat.sprink	0	0	0	0	5500
9.wheat.wheat.sprink	0	0	0	0	4400
10.wheat.wheat.sprink	0	0	0	0	4620
8.wheat.wheat.rain	0	0	0	280	0
1.barley.barley.flood	3200	3070	3070	3070	2610
2.barley.barley.flood	3000	3190	2510		
3.barley.barley.flood	3200	3190	2510		
4.barley.barley.flood	3000	3200	2510	2070	
1.barley.barley.sprink	3520	3377	3377	3377	2871
2.barley.barley.sprink	3300	3509	2761		
3.barley.barley.sprink	3520	3509	2761		
4.barley.barley.sprink	3300	3520	2761	2277	
1.barley.barley.rain	1422	1168	628	390	320
2.barley.barley.rain	1720	1242	954		
3.barley.barley.rain	1908	1388	1218		
4.barley.barley.rain	1304	874	292	202	
5.barley.barley.flood	0	0	2750	2750	2350
6.barley.barley.flood	0	0	3200	3150	2700
7.barley.barley.flood	0	2770	2650	2384	0
5.barley.barley.sprink	0	0	3025	3025	2585
6.barley.barley.sprink	0	0	3520	3465	2970
7.barley.barley.sprink	0	3047	2915	2622	0
5.barley.barley.rain	0	0	574	222	0
6.barley.barley.rain	0	0	696	300	0
7.barley.barley.rain	0	1174	556	190	0
8*10.barley.barley.flood	0	0	0	3040	3040
8*10.barley.barley.sprink	0	0	0	3344	3344
8.barley.barley.rain	0	0	0	260	0
1*4.intmaiz.maize.flood	2500	2500	2500	2500	2500
1*4.intmaiz.maize.sprink	2750	2750	2750	2750	2750
5.intmaiz.maize.flood	0	0	5080	5080	4588
6.intmaiz.maize.flood	0	0	3764	3764	3764
7.intmaiz.maize.flood	0	3102	3102	3102	0
5.intmaiz.maize.sprink	0	0	5588	5588	5047
6.intmaiz.maize.sprink	0	0	4140	4140	4140
7.intmaiz.maize.sprink	0	3412	3412	3412	0
8.intmaiz.maize.flood	0	0	0	0	3370
9.intmaiz.maize.flood	0	0	0	0	3330
10.intmaiz.maize.flood	0	0	0	0	3540
8.intmaiz.maize.sprink	0	0	0	0	3707
9.intmaiz.maize.sprink	0	0	0	0	3663
10.intmaiz.maize.sprink	0	0	0	0	3894
1.lentil.lentil.rain	1156	906	434	0	0
2.lentil.lentil.rain	1098	784	434	0	0
3.lentil.lentil.rain	1114	784	434	0	0
4.lentil.lentil.rain	1112	960	434	0	0
5*10.lentil.lentil.rain	0	900	0	0	0
1*10.lentil.lentil.flood	1100	1100	1100	1100	1100
1*10.lentil.lentil.sprink	1210	1210	1210	1210	1210
1*10.chick.chickpea.rain	990	540	220	0	0
1*10.chick.chickpea.flood	1000	1000	1000	1000	1000
1*10.chick.chickpea.sprink	1100	1100	1100	1100	1100
1*4.bdbean.broadbean.flood	1200	1200	1200	1200	1200
1*4.bdbean.broadbean.sprink	1320	1320	1320	1320	1320
1*4.bdbean.broadbean.rain	500	500	500	500	500
5.bdbean.broadbean.flood	0	0	1769	1769	2138
6.bdbean.broadbean.flood	0	0	2794	2794	2794
7.bdbean.broadbean.flood	0	2183	3029	3029	0
5.bdbean.broadbean.sprink	0	0	1946	1946	2351
6.bdbean.broadbean.sprink	0	0	3073	3073	3073
7.bdbean.broadbean.sprink	0	2401	3332	3332	0
8*10.bdbean.broadbean.flood	0	0	0	0	1800
8*10.bdbean.broadbean.sprink	0	0	0	0	1980
1*7.sybean.soybean.flood	1700	1700	1700	1650	1650
1*7.sybean.soybean.sprink	1870	1870	1870	1715	1715
1.autsugar.sugarbeet.flood	45000	45000	45000	43000	41090

2.autsugar.sugarbeet.flood	45000	45000	35280	36060	30130
3.autsugar.sugarbeet.flood	36315	36315	36275	36060	0
4.autsugar.sugarbeet.flood	36315	36315	36275	36060	0
1.autsugar.sugarbeet.sprink	49500	49500	49500	47300	45199
2.autsugar.sugarbeet.sprink	49500	49500	38808	39666	33143
3.autsugar.sugarbeet.sprink	39947	39947	39903	39666	0
4.autsugar.sugarbeet.sprink	39947	39947	39903	39666	0
5.autsugar.sugarbeet.flood	0	0	45000	45000	45090
6.autsugar.sugarbeet.flood	0	0	35280	36060	35130
7.autsugar.sugarbeet.flood	0	36315	36275	36060	0
5.autsugar.sugarbeet.sprink	0	0	49500	49500	49599
6.autsugar.sugarbeet.sprink	0	0	38808	39666	33143
7.autsugar.sugarbeet.sprink	0	39947	39903	39666	0
8.autsugar.sugarbeet.flood	0	0	0	35500	35500
9.autsugar.sugarbeet.flood	0	0	0	0	38900
10.autsugar.sugarbeet.flood	0	0	0	0	37650
8.autsugar.sugarbeet.sprink	0	0	0	39050	39050
9.autsugar.sugarbeet.sprink	0	0	0	0	42790
10.autsugar.sugarbeet.sprink	0	0	0	0	41415

1*10.winsugar.sugarbeet.flood	43000	43000	43000	43000	43000
1*10.winsugar.sugarbeet.sprink	44000	44000	44000	44000	44000

1*4.sesame.sesame.flood	1200	1200	1200	1200	1200
1*4.sesame.sesame.sprink	1220	1220	1220	1220	1220
5.sesame.sesame.flood	0	0	1200	1031	1017
6.sesame.sesame.flood	0	0	1290	1245	1200
7.sesame.sesame.flood	0	1170	1125	1020	0
5.sesame.sesame.sprink	0	0	1320	1134	1119
6.sesame.sesame.sprink	0	0	1419	1370	1320
7.sesame.sesame.sprink	0	1287	1238	1122	0
8*10.sesame.sesame.flood	0	0	0	0	1400
8*10.sesame.sesame.sprink	0	0	0	0	1540

1*10.peanut.peanut.flood	3000	3000	3000	3000	2500
1*10.peanut.peanut.sprink	2750	2750	2750	2750	2750
1*10.peanut.peanut.drip	2875	2875	2875	2875	2875

1.cumin.cumin.rain	915	875	500	0	0
2.cumin.cumin.rain	877	875	500	0	0
3.cumin.cumin.rain	953	875	500	0	0
4.cumin.cumin.rain	900	800	500	0	0
5.cumin.cumin.rain	0	0	450	0	0
6.cumin.cumin.rain	0	0	450	0	0
7*10.cumin.cumin.rain	0	920	450	0	0
1*7.cumin.cumin.flood	1000	1000	1000	1000	1000
8*10.cumin.cumin.flood	600	600	600	600	600
1*7.cumin.cumin.sprink	1100	1100	1100	1100	1100
8*10.cumin.cumin.sprink	660	660	660	660	660

1.cotton.cotton.flood	5280	4640	4460	4040	4080
2.cotton.cotton.flood	4310	3980	3940		
3.cotton.cotton.flood	4380	4840	4670		
4.cotton.cotton.flood	4783	4840	5570	4520	
1.cotton.cotton.sprink	5808	5104	4906	4444	4488
2.cotton.cotton.sprink	4741	4378	4334		
3.cotton.cotton.sprink	4818	5324	5137		
4.cotton.cotton.sprink	5261	5324	6127	4972	
1.cotton.cotton.drip	6072	5336	5129	4646	4692
2.cotton.cotton.drip	4957	4577	4531		
3.cotton.cotton.drip	5037	5566	5371		
4.cotton.cotton.drip	5500	5566	6406	5198	
5.cotton.cotton.flood	0	0	4190	4190	4290
6.cotton.cotton.flood	0	0	5420	4420	3760
7.cotton.cotton.flood	0	4310	3660	3660	0
5.cotton.cotton.sprink	0	0	4609	4609	4719
6.cotton.cotton.sprink	0	0	5962	4862	4136
7.cotton.cotton.sprink	0	4741	4026	4026	0
5.cotton.cotton.drip	0	0	4819	4819	4934
6.cotton.cotton.drip	0	0	6233	5083	4324
7.cotton.cotton.drip	0	4957	4209	4209	0
8.cotton.cotton.flood	0	0	0	3100	3100
9.cotton.cotton.flood	0	0	0	0	3820
10.cotton.cotton.flood	0	0	0	0	4020
8.cotton.cotton.sprink	0	0	0	3410	3410
9.cotton.cotton.sprink	0	0	0	0	4202
10.cotton.cotton.sprink	0	0	0	0	4422
8.cotton.cotton.drip	0	0	0	3565	3565

```
9.cotton.cotton.drip                   0        0        0        0      4393
10.cotton.cotton.drip                  0        0        0        0      4623

1*4.summelon.wmelonsum.flood        50000    50000    50000    50000    50000
1*4.summelon.wmelonsum.sprink       55000    55000    55000    55000    55000
1*4.summelon.wmelonsum.drip         57500    57500    57500    57500    57500
5*7.summelon.wmelonsum.flood          0      33000    33000    33000    33000
5*7.summelon.wmelonsum.sprink         0      36300    36300    36300    36300
5*7.summelon.wmelonsum.drip           0      37950    37950    37950    37950
8*10.summelon.wmelonsum.flood         0        0        0        0      20000
8*10.summelon.wmelonsum.sprink        0        0        0        0      22000
8*10.summelon.wmelonsum.drip          0        0        0        0      23000

1*4.autmelon.wmelonaut.flood        25000    25000    25000    25000    25000
1*4.autmelon.wmelonaut.sprink       27500    27500    27500    27500    27500
1*4.autmelon.wmelonaut.drip         28750    28750    28750    28750    28750
1*4.autmelon.wmelonaut.rain         10000      0        0        0        0
5.autmelon.wmelonaut.flood            0        0      20640    20640    26564
6.autmelon.wmelonaut.flood            0        0      20640    30000    19547
7.autmelon.wmelonaut.flood            0      26458    20640    20640
5.autmelon.wmelonaut.sprink           0        0      22704    22704    29220
6.autmelon.wmelonaut.sprink           0        0      22704    33000    21502
7.autmelon.wmelonaut.sprink           0      29104    22704    22704      0
5.autmelon.wmelonaut.drip             0        0      23736    23736    30549
6.autmelon.wmelonaut.drip             0        0      23736    34500    22479
7.autmelon.wmelonaut.drip             0      30427    23736    23736      0
8.autmelon.wmelonaut.flood           0        0        0        0      30150
9.autmelon.wmelonaut.flood           0        0        0        0      30330
10.autmelon.wmelonaut.flood          0        0        0        0      30000
8.autmelon.wmelonaut.sprink          0        0        0        0      33165
9.autmelon.wmelonaut.sprink          0        0        0        0      33363
10.autmelon.wmelonaut.sprink         0        0        0        0      33000
8.autmelon.wmelonaut.drip            0        0        0        0      38140
9.autmelon.wmelonaut.drip            0        0        0        0      38367
10.autmelon.wmelonaut.drip           0        0        0        0      37950

1*10.sprptt.potato.flood              20000    20000    20000    20000    20000
1*10.sprptt.potato.sprink             22000    22000    22000    22000    22000
1*10.sprptt.potato.drip               23000    23000    23000    23000    23000

1*4.sumtmt.tomato.flood               35000    35000    35000    35000    35000
1*4.sumtmt.tomato.drip                40250    40250    40250    40250    40250
5*7.sumtmt.tomato.flood                 0      27000    27000    27000    27000
5*7.sumtmt.tomato.drip                  0      31050    31050    31050    31050
8*10.sumtmt.tomato.flood                0        0        0        0      20000
8*10.sumtmt.tomato.drip                 0        0        0        0      23000

1*4.sumegg.eggplant.flood             25000    25000    25000    25000    25000
1*4.sumegg.eggplant.drip              28750    28750    28750    28750    28750
5*7.sumegg.eggplant.flood               0      20000    20000    20000    20000
5*7.sumegg.eggplant.drip                0      23000    23000    23000    23000
8*10.sumegg.eggplant.flood              0        0        0        0      13000
8*10.sumegg.eggplant.drip               0        0        0        0      14950
```

I.3.2. irrigation requirements (cubic meter/ha)

```
table waterreq(rr,agz,c,irr,t)
* irrigation requirement by mantika, agro-climatic zone, crop, irrigation method
* and month (cubic meters per hectare per month)
                                     Jan        Feb        Mar        Apr        May        Jun

 1*4.1.wheat.flood                    0          0          783        1198       1546       1216

 1*4.2.wheat.flood                    0          0          880        1348       1739       1368

 1*4.3.wheat.flood                    0          0          978        1498       1932       1520

 1*4.4.wheat.flood                    0          0          1174       1798       2319       1824

 1*4.5.wheat.flood                    0          0          1467       2247       2898       2281

 1*4.1.wheat.sprink                   0          0          704        1079       1391       1095

 1*4.2.wheat.sprink                   0          0          792        1213       1565       1232

 1*4.3.wheat.sprink                   0          0          880        1348       1739       1368

 1*4.4.wheat.sprink                   0          0          1057       1618       2087       1642

 1*4.5.wheat.sprink                   0          0          1321       2022       2609       2053

 5*7.1*2.wheat.flood                  0          0          1027       1841       2243       1328
```

5*7.3.wheat.flood	0	44	1404	2011	2259	1651
5*7.4.wheat.flood	0	340	1922	2227	2653	1628
5*7.5.wheat.flood	242	577	1931	2636	2832	1595
5*7.1*2.wheat.sprink	0	0	924	1657	2020	1195
5*7.3.wheat.sprink	0	39	1264	1809	2032	1487
5*7.4.wheat.sprink	0	306	1731	2004	2388	1466
5*7.5.wheat.sprink	218	519	1738	2372	2549	1435
8*10.1*5.wheat.flood	67	833	1991	2548	2809	1775
8*10.1*5.wheat.sprink	61	749	1792	2294	2528	1598
1*4.1.barley.flood	0	0	754	703	913	0
1*4.2.barley.flood	0	0	848	791	1027	0
1*4.3.barley.flood	0	0	942	879	1141	0
1*4.4.barley.flood	0	640	1130	1055	1369	0
1*4.5.barley.flood	0	960	1413	1318	1711	0
1*4.1.barley.sprink	0	0	678	633	821	0
1*4.2.barley.sprink	0	0	763	712	924	0
1*4.3.barley.sprink	0	0	848	791	1027	0
1*4.4.barley.sprink	0	576	1017	949	1232	0
1*4.5.barley.sprink	0	864	1272	1187	1540	0
5*7.1*2.barley.flood	0	290	1101	1287	1290	0
5*7.3.barley.flood	0	322	1223	1430	1434	0
5*7.4.barley.flood	0	404	1528	1588	1593	0
5*7.5.barley.flood	189	577	1910	1765	1770	0
5*7.1*2.barley.sprink	0	262	989	1158	1161	0
5*7.3.barley.sprink	0	290	1101	1287	1290	0
5*7.4.barley.sprink	0	363	1375	1430	1434	0
5*7.5.barley.sprink	170	519	1719	1588	1593	0
8*10.1*5.barley.flood	27	695	1642	1401	1456	0
8*10.1*5.barley.sprink	24	625	1477	1262	1312	0
1*7.1*5.intmaiz.flood	0	0	0	0	0	2133
1*7.1*5.intmaiz.sprink	0	0	0	0	0	1920
8*10.1*5.intmaiz.flood	0	0	0	0	0	1971
8*10.1*5.intmaiz.sprink	0	0	0	0	0	1775
1*10.1.lentil.flood	0	0	0	912	912	0
1*10.2.lentil.flood	0	0	0	1064	1064	0
1*10.3.lentil.flood	0	0	0	1327	1327	0
1*10.4.lentil.flood	0	0	760	1520	1520	0
1*10.5.lentil.flood	0	0	760	1672	1672	0
1*10.1.lentil.sprink	0	0	0	821	821	0
1*10.2.lentil.sprink	0	0	0	958	958	0
1*10.3.lentil.sprink	0	0	0	1195	1195	0
1*10.4.lentil.sprink	0	0	684	1368	1368	0
1*10.5.lentil.sprink	0	0	684	1505	1505	0
1*10.1.chick.flood	0	0	0	912	912	0
1*10.2.chick.flood	0	0	0	1064	1064	0

1*10.3.chick.flood	0	0	0	1327	1327	0
1*10.4.chick.flood	0	0	760	1520	1520	0
1*10.5.chick.flood	0	0	760	1672	1672	0
1*10.1.chick.sprink	0	0	0	821	821	0
1*10.2.chick.sprink	0	0	0	958	958	0
1*10.3.chick.sprink	0	0	0	1195	1195	0
1*10.4.chick.sprink	0	0	684	1368	1368	0
1*10.5.chick.sprink	0	0	684	1505	1505	0
1*10.1*2.bdbean.flood	0	380	1143	2169	2137	0
1*10.3*5.bdbean.flood	0	836	1237	2348	2315	0
1*10.1*2.bdbean.sprink	0	342	1029	1952	1923	0
1*10.3*5.bdbean.sprink	0	752	1114	2114	2084	0
1*10.1*5.sybean.flood	0	0	0	0	1199	2824
1*10.1*5.sybean.sprink	0	0	0	0	1079	2541
1*7.1*2.autsugar.flood	0	0	1195	3227	5540	7685
1*7.3.autsugar.flood	0	0	1797	3517	5646	9470
1*7.4.autsugar.flood	0	186	2922	3894	6468	9264
1*7.5.autsugar.flood	205	772	2919	4588	6979	9149
1*7.1*2.autsugar.sprink	0	0	1074	2903	4986	6917
1*7.3.autsugar.sprink	0	0	1618	3167	5082	8523
1*7.4.autsugar.sprink	0	166	2628	3505	5822	8338
1*7.5.autsugar.sprink	184	694	2627	4129	6280	8234
8*10.1*5.autsugar.flood	0	872	2434	3589	5600	8150
8*10.1*5.autsugar.sprink	0	784	2190	3230	5040	7336
1*10.1.winsugar.flood	0	0	357	1769	2876	4341
1*10.2.winsugar.flood	0	0	429	2123	3450	5211
1*10.3.winsugar.flood	0	760	465	2300	3738	5644
1*10.4*5.winsugar.flood	0	912	537	2654	4314	6513
1*10.1.winsugar.sprink	0	0	322	1593	2589	3908
1*10.2.winsugar.sprink	0	0	386	1911	3105	4689
1*10.3.winsugar.sprink	0	684	418	2070	3364	5080
1*10.4*5.winsugar.sprink	0	821	483	2388	3882	5861
1*7.1*5.sesame.flood	0	0	0	0	0	0
1*7.1*5.sesame.sprink	0	0	0	0	0	0
8*10.1*5.sesame.flood	0	0	0	0	0	0
8*10.1*5.sesame.sprink	0	0	0	0	0	0
1*10.1.peanut.flood	0	0	0	2280	3040	3040
1*10.2.peanut.flood	0	0	0	2736	3648	3648
1*10.3.peanut.flood	0	0	0	2964	3952	3952
1*10.4*5.peanut.flood	0	0	0	3420	4560	4560
1*10.1.peanut.sprink	0	0	0	2052	2736	2736
1*10.2.peanut.sprink	0	0	0	2462	3283	3283
1*10.3.peanut.sprink	0	0	0	2668	3557	3557

1*10.4*5.peanut.sprink	0	0	0	3078	4104	4104
1*10.1.peanut.drip	0	0	0	1824	2432	2432
1*10.2.peanut.drip	0	0	0	2189	2918	2918
1*10.3.peanut.drip	0	0	0	2371	3162	3162
1*10.4*5.peanut.drip	0	0	0	2736	3648	3648
1*10.1.cumin.flood	0	0	760	1216	0	0
1*10.2.cumin.flood	0	0	912	1459	0	0
1*10.3.cumin.flood	0	0	988	1581	0	0
1*10.4.cumin.flood	0	0	1140	1824	0	0
1*10.5.cumin.flood	0	0	1216	1976	0	0
1*10.1.cumin.sprink	0	0	684	1094	0	0
1*10.2.cumin.sprink	0	0	821	1313	0	0
1*10.3.cumin.sprink	0	0	889	1423	0	0
1*10.4.cumin.sprink	0	0	1026	1642	0	0
1*10.5.cumin.sprink	0	0	1094	1778	0	0
1*4.1*5.cotton.flood	0	0	0	1230	1806	2829
1*4.1*5.cotton.sprink	0	0	0	1107	1625	2546
1*4.1*5.cotton.drip	0	0	0	984	1444	2263
5*7.1*5.cotton.flood	0	0	0	2471	3069	4457
5*7.1*5.cotton.sprink	0	0	0	2223	2763	4011
5*7.1*5.cotton.drip	0	0	0	1977	2455	3567
8*10.1*5.cotton.flood	0	0	0	2174	2639	3286
8*10.1*5.cotton.sprink	0	0	0	1956	2374	2958
8*10.1*5.cotton.drip	0	0	0	1739	2111	2630
1*7.1*5.autmelon.flood	0	0	0	0	0	2949
1*7.1*5.autmelon.sprink	0	0	0	0	0	2654
1*7.1*5.autmelon.drip	0	0	0	0	0	2359
8*10.1*5.autmelon.flood	0	0	0	0	0	2529
8*10.1*5.autmelon.sprink	0	0	0	0	0	2277
8*10.1*5.autmelon.drip	0	0	0	0	0	2023
1*10.1*5.summelon.flood	0	0	0	0	0	3417
1*10.1*5.summelon.sprink	0	0	0	0	0	3075
1*10.1*5.summelon.drip	0	0	0	0	0	2733
1*7.1*5.sprptt.flood	0	0	904	2768	4619	4949
1*7.1*5.sprptt.sprink	0	0	815	2491	4157	4454
1*7.1*5.sprptt.drip	0	0	724	2215	3695	3960
8*10.1*5.sprptt.flood	0	325	1192	2364	3789	4656
8*10.1*5.sprptt.sprink	0	292	1072	2126	3411	4191
8*10.1*5.sprptt.drip	0	260	953	1891	3032	3726
1*10.1*5.sumtmt.flood	0	0	0	0	2181	4106
1*10.1*5.sumtmt.drip	0	0	0	0	1745	3285
1*10.1*5.sumegg.flood	0	0	0	0	1841	3119

1*10.1*5.sumegg.drip	0	0	0	0	1473	2494
+	Jul	Aug	Sep	Oct	Nov	Dec
1*4.1.wheat.flood	0	0	0	0	243	0
1*4.2.wheat.flood	0	0	0	0	273	0
1*4.3.wheat.flood	0	0	0	0	304	0
1*4.4.wheat.flood	0	0	0	0	365	0
1*4.5.wheat.flood	0	0	0	0	456	0
1*4.1.wheat.sprink	0	0	0	0	219	0
1*4.2.wheat.sprink	0	0	0	0	246	0
1*4.3.wheat.sprink	0	0	0	0	273	0
1*4.4.wheat.sprink	0	0	0	0	328	0
1*4.5.wheat.sprink	0	0	0	0	410	0
5*7.1*2.wheat.flood	0	0	0	0	62	0
5*7.3.wheat.flood	0	0	0	0	359	0
5*7.4.wheat.flood	0	0	0	0	382	0
5*7.5.wheat.flood	0	0	0	0	379	221
5*7.1*2.wheat.sprink	0	0	0	0	57	0
5*7.3.wheat.sprink	0	0	0	0	324	0
5*7.4.wheat.sprink	0	0	0	0	343	0
5*7.5.wheat.sprink	0	0	0	0	342	198
8*10.1*5.wheat.flood	0	0	0	0	476	82
8*10.1*5.wheat.sprink	0	0	0	0	429	74
1*4.1.barley.flood	0	0	0	0	243	0
1*4.2.barley.flood	0	0	0	0	273	0
1*4.3.barley.flood	0	0	0	0	304	0
1*4.4.barley.flood	0	0	0	0	365	0
1*4.5.barley.flood	0	0	0	0	456	0
1*4.1.barley.sprink	0	0	0	0	219	0
1*4.2.barley.sprink	0	0	0	0	246	0
1*4.3.barley.sprink	0	0	0	0	273	0
1*4.4.barley.sprink	0	0	0	0	328	0
1*4.5.barley.sprink	0	0	0	0	410	0
5*7.1*2.barley.flood	0	0	0	0	294	0
5*7.3.barley.flood	0	0	0	0	306	165
5*7.4.barley.flood	0	0	0	0	342	182
5*7.5.barley.flood	0	0	0	0	379	228
5*7.1*2.barley.sprink	0	0	0	0	248	9
5*7.3.barley.sprink	0	0	0	0	276	149
5*7.4.barley.sprink	0	0	0	0	306	165
5*7.5.barley.sprink	0	0	0	0	342	205
8*10.1*5.barley.flood	0	0	0	0	397	73
8*10.1*5.barley.sprink	0	0	0	0	357	65
1*7.1*5.intmaiz.flood	3074	4832	4037	883	0	0
1*7.1*5.intmaiz.sprink	2768	4349	3634	795	0	0
8*10.1*5.intmaiz.flood	2769	4365	3657	686	0	0
8*10.1*5.intmaiz.sprink	2493	3929	3291	617	0	0

1*10.1.lentil.flood	0	0	0	0	0	0
1*10.2.lentil.flood	0	0	0	0	0	0
1*10.3.lentil.flood	0	0	0	0	0	0
1*10.4.lentil.flood	0	0	0	0	0	0
1*10.5.lentil.flood	0	0	0	0	0	0
1*10.1.lentil.sprink	0	0	0	0	0	0
1*10.2.lentil.sprink	0	0	0	0	0	0
1*10.3.lentil.sprink	0	0	0	0	0	0
1*10.4.lentil.sprink	0	0	0	0	0	0
1*10.5.lentil.sprink	0	0	0	0	0	0
1*10.1.chick.flood	0	0	0	0	0	0
1*10.2.chick.flood	0	0	0	0	0	0
1*10.3.chick.flood	0	0	0	0	0	0
1*10.4.chick.flood	0	0	0	0	0	0
1*10.5.chick.flood	0	0	0	0	0	0
1*10.1.chick.sprink	0	0	0	0	0	0
1*10.2.chick.sprink	0	0	0	0	0	0
1*10.3.chick.sprink	0	0	0	0	0	0
1*10.4.chick.sprink	0	0	0	0	0	0
1*10.5.chick.sprink	0	0	0	0	0	0
1*10.1*2.bdbean.flood	0	0	0	0	0	0
1*10.3*5.bdbean.flood	0	0	0	0	0	0
1*10.1*2.bdbean.sprink	0	0	0	0	0	0
1*10.3*5.bdbean.sprink	0	0	0	0	0	0
1*10.1*5.sybean.flood	4220	3051	0	0	0	0
1*10.1*5.sybean.sprink	3797	2745	0	0	0	0
1*7.1*2.autsugar.flood	0	0	0	0	11	0
1*7.3.autsugar.flood	0	0	0	0	577	0
1*7.4.autsugar.flood	0	0	0	0	612	0
1*7.5.autsugar.flood	0	0	0	0	605	64
1*7.1*2.autsugar.sprink	0	0	0	0	9	0
1*7.3.autsugar.sprink	0	0	0	0	519	0
1*7.4.autsugar.sprink	0	0	0	0	550	0
1*7.5.autsugar.sprink	0	0	0	0	545	58
8*10.1*5.autsugar.flood	0	0	0	0	616	0
8*10.1*5.autsugar.sprink	0	0	0	0	553	0
1*10.1.winsugar.flood	2312	0	0	0	0	0
1*10.2.winsugar.flood	2776	0	0	0	0	0
1*10.3.winsugar.flood	3007	0	0	0	0	0
1*10.4*5.winsugar.flood	3469	0	0	0	0	0
1*10.1.winsugar.sprink	2081	0	0	0	0	0
1*10.2.winsugar.sprink	2497	0	0	0	0	0
1*10.3.winsugar.sprink	2706	0	0	0	0	0

1*10.4*5.winsugar.sprink	3122	0	0	0	0	0
1*7.1*5.sesame.flood	4213	3868	2695	0	0	0
1*7.1*5.sesame.sprink	3792	3482	2424	0	0	0
8*10.1*5.sesame.flood	4213	3868	2695	0	0	0
8*10.1*5.sesame.sprink	3792	3482	2424	0	0	0
1*10.1.peanut.flood	0	0	0	0	0	0
1*10.2.peanut.flood	0	0	0	0	0	0
1*10.3.peanut.flood	0	0	0	0	0	0
1*10.4*5.peanut.flood	0	0	0	0	0	0
1*10.1.peanut.sprink	0	0	0	0	0	0
1*10.2.peanut.sprink	0	0	0	0	0	0
1*10.3.peanut.sprink	0	0	0	0	0	0
1*10.4*5.peanut.sprink	0	0	0	0	0	0
1*10.1.peanut.drip	0	0	0	0	0	0
1*10.2.peanut.drip	0	0	0	0	0	0
1*10.3.peanut.drip	0	0	0	0	0	0
1*10.4*5.peanut.drip	0	0	0	0	0	0
1*10.1.cumin.flood	0	0	0	0	0	0
1*10.2.cumin.flood	0	0	0	0	0	0
1*10.3.cumin.flood	0	0	0	0	0	0
1*10.4.cumin.flood	0	0	0	0	0	0
1*10.5.cumin.flood	0	0	0	0	0	0
1*10.1.cumin.sprink	0	0	0	0	0	0
1*10.2.cumin.sprink	0	0	0	0	0	0
1*10.3.cumin.sprink	0	0	0	0	0	0
1*10.4.cumin.sprink	0	0	0	0	0	0
1*10.5.cumin.sprink	0	0	0	0	0	0
1*4.1*5.cotton.flood	4391	4156	3309	0	0	0
1*4.1*5.cotton.sprink	3952	3740	2978	0	0	0
1*4.1*5.cotton.drip	3513	3324	2647	0	0	0
5*7.1*5.cotton.flood	5645	6142	4466	0	0	0
5*7.1*5.cotton.sprink	5080	5528	4018	0	0	0
5*7.1*5.cotton.drip	4515	4914	3572	0	0	0
8*10.1*5.cotton.flood	5057	5504	3972	0	0	0
8*10.1*5.cotton.sprink	4551	4954	3575	0	0	0
8*10.1*5.cotton.drip	4046	4403	3178	0	0	0
1*7.1*5.autmelon.flood	1581	2341	2812	0	0	0
1*7.1*5.autmelon.sprink	1423	2107	2531	0	0	0
1*7.1*5.autmelon.drip	1265	1873	2250	0	0	0
8*10.1*5.autmelon.flood	2380	2633	2497	0	0	0
8*10.1*5.autmelon.sprink	2142	2370	2248	0	0	0
8*10.1*5.autmelon.drip	1905	2107	1997	0	0	0
1*10.1*5.summelon.flood	3265	2918	0	0	0	0

1*10.1*5.summelon.sprink	2938	2627	0	0	0	0
1*10.1*5.summelon.drip	2611	2335	0	0	0	0
1*7.1*5.sprptt.flood	0	0	0	0	0	0
1*7.1*5.sprptt.sprink	0	0	0	0	0	0
1*7.1*5.sprptt.drip	0	0	0	0	0	0
8*10.1*5.sprptt.flood	0	0	0	0	0	0
8*10.1*5.sprptt.sprink	0	0	0	0	0	0
8*10.1*5.sprptt.drip	0	0	0	0	0	0
1*10.1*5.sumtmt.flood	4271	2175	0	0	0	0
1*10.1*5.sumtmt.drip	3417	1740	0	0	0	0
1*10.1*5.sumegg.flood	4148	2455	0	0	0	0
1*10.1*5.sumegg.drip	3318	1964	0	0	0	0

I.3.3. labour requirements by month (hour/ha)

table labourreq(rr,agz,c,irr,t)

	Jan	Feb	Mar	Apr	May	Jun
1*10.1*5.wheat.(flood,sprink,drip)	0	4	13	22	17	0
1*10.1*5.wheat.rain	0	0	0	0	0	0
1*10.1*5.barley.(flood,sprink,drip)	0	4	13	17	9	0
1*10.1*5.barley.rain	0	0	0	0	0	0
1*10.1*5.intmaiz.(flood,sprink,drip,rain)	0	0	0	0	0	52
1*10.1.lentil.rain	2	0	1	0	201	0
1*10.2.lentil.rain	6	0	0	0	221	0
1*10.3*5.lentil.rain	3	0	0	0	0	150
1*10.1*5.lentil.(flood,sprink,drip)	23	13	14	10	13	118
1*10.1.chick.rain	0	0	2	0	3	118
1*10.2.chick.rain	0	0	2	0	1	91
1*10.3*5.chick.rain	0	0	2	0	1	50
1*10.1*5.chick.(flood,sprink,drip)	23	13	14	10	13	118
1*10.1*5.bdbean.(flood,sprink,drip)	0	53	94	29	58	90
1*10.1*5.sybean.(flood,sprink,drip,rain)	0	0	0	0	30	30
1*5.1*3.autsugar.(flood,sprink,drip)	57	5	12	25	36	272
1*5.4.autsugar.(flood,sprink,drip)	57	5	12	25	36	260
1*5.5.autsugar.(flood,sprink,drip)	57	5	12	25	36	248
6.1*3.autsugar.(flood,sprink,drip)	57	5	12	25	36	213
6.4.autsugar.(flood,sprink,drip)	57	5	12	25	36	218
6.5.autsugar.(flood,sprink,drip)	57	5	12	25	36	182
7.1*2.autsugar.(flood,sprink,drip)	57	5	12	25	36	220
7.3.autsugar.(flood,sprink,drip)	57	5	12	25	36	219

7.4*5.autsugar.(flood,sprink,drip)	57	5	12	25	36	218
8*10.1*5.autsugar.(flood,sprink,drip)	57	5	12	25	36	281
1*10.1*5.winsugar.(flood,sprink,drip)	57	5	0	12	25	36
1*10.1*5.sesame.(flood,sprink,drip,rain)	0	0	0	0	0	0
1*10.1*5.peanut.(flood,sprink,drip,rain)	0	24	44	109	82	71
1*10.1.cumin.rain	2	0	1	0	247	0
1*10.2.cumin.rain	6	0	0	0	236	0
1*10.3.cumin.rain	3	0	0	0	0	165
1*10.4*5.cumin.rain	3	0	0	0	0	110
1*10.1*5.cumin.(flood,sprink,drip)	2	0	10	10	247	0
1.1.cotton.(flood,sprink,drip)	0	0	0	97	40	208
1.2.cotton.(flood,sprink,drip)	0	0	0	97	40	208
1.3.cotton.(flood,sprink,drip)	0	0	0	97	40	208
1.4.cotton.(flood,sprink,drip)	0	0	0	97	40	208
1.5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
2.1.cotton.(flood,sprink,drip)	0	0	0	97	40	208
2.2.cotton.(flood,sprink,drip)	0	0	0	97	40	208
2.3*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
3.1.cotton.(flood,sprink,drip)	0	0	0	97	40	208
3.2.cotton.(flood,sprink,drip)	0	0	0	97	40	208
3.3*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
4.1.cotton.(flood,sprink,drip)	0	0	0	97	40	208
4.2.cotton.(flood,sprink,drip)	0	0	0	97	40	208
4.3.cotton.(flood,sprink,drip)	0	0	0	97	40	208
4.4*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
5.1*3.cotton.(flood,sprink,drip)	0	0	0	87	30	198
5.4.cotton.(flood,sprink,drip)	0	0	0	87	30	198
5.5.cotton.(flood,sprink,drip)	0	0	0	87	30	198
6.1*3.cotton.(flood,sprink,drip)	0	0	0	87	30	198
6.4.cotton.(flood,sprink,drip)	0	0	0	87	30	198
6.5.cotton.(flood,sprink,drip)	0	0	0	87	30	198
7.1*2.cotton.(flood,sprink,drip)	0	0	0	87	30	198
7.3.cotton.(flood,sprink,drip)	0	0	0	87	30	198
7.4*5.cotton.(flood,sprink,drip)	0	0	0	87	30	198
8.1*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
9.1*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
10.1*5.cotton.(flood,sprink,drip)	0	0	0	97	40	208
1*10.1*5.autmelon.(flood,sprink,drip)	0	0	0	0	0	194
1*10.1*5.autmelon.rain	0	0	0	0	0	94
1*10.1*5.summelon.(flood,sprink,drip)	0	0	0	0	194	304
1*10.1*5.summelon.rain	0	0	0	0	94	54

1*10.1*5.sprptt.(flood,sprink,drip,rain)	60	43	36	52	32	609
1*10.1*5.sumtmt.(flood,sprink,drip,rain)	0	0	0	0	0	152
1*10.1*3.sumegg.(flood,sprink,drip,rain)	0	0	0	128	101	81
+	Jul	Aug	Sep	Oct	Nov	Dec
1*10.1*5.wheat.(flood,sprink,drip)	0	0	0	23	13	7
1*10.1*5.wheat.rain	0	0	0	0	2	0
1*10.1*5.barley.(flood,sprink,drip)	0	0	0	23	13	7
1*10.1*5.barley.rain	0	0	0	0	2	0
1*10.1*5.intmaiz.(flood,sprink,drip,rain)	89	43	29	63	0	0
1*10.1.lentil.rain	0	0	0	0	0	0
1*10.2.lentil.rain	0	0	0	0	0	0
1*10.3*5.lentil.rain	0	0	0	0	0	0
1*10.1*5.lentil.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1.chick.rain	0	0	0	0	0	0
1*10.2.chick.rain	0	0	0	0	0	0
1*10.3*5.chick.rain	0	0	0	0	0	0
1*10.1*5.chick.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1*5.bdbean.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1*5.sybean.(flood,sprink,drip,rain)	30	40	0	0	0	0
1*5.1*3.autsugar.(flood,sprink,drip)	241	0	0	108	99	0
1*5.4.autsugar.(flood,sprink,drip)	230	0	0	108	99	0
1*5.5.autsugar.(flood,sprink,drip)	220	0	0	108	99	0
6.1*3.autsugar.(flood,sprink,drip)	189	0	0	108	99	0
6.4.autsugar.(flood,sprink,drip)	193	0	0	108	99	0
6.5.autsugar.(flood,sprink,drip)	161	0	0	108	99	0
7.1*2.autsugar.(flood,sprink,drip)	194	0	0	108	99	0
7.3.autsugar.(flood,sprink,drip)	194	0	0	108	99	0
7.4*5.autsugar.(flood,sprink,drip)	193	0	0	108	99	0
8*10.1*5.autsugar.(flood,sprink,drip)	248	0	0	108	99	0
1*10.1*5.winsugar.(flood,sprink,drip)	653	201	0	0	108	99
1*10.1*5.sesame.(flood,sprink,drip,rain)	40	40	390	0	0	0
1*10.1*5.peanut.(flood,sprink,drip,rain)	283	0	0	0	0	0
1*10.1.cumin.rain	0	0	0	0	0	0
1*10.2.cumin.rain	0	0	0	0	0	0
1*10.3.cumin.rain	0	0	0	0	0	0

1*10.4*5.cumin.rain	0	0	0	0	0	0
1*10.1*5.cumin.(flood,sprink,drip)	0	0	0	0	0	0
1.1.cotton.(flood,sprink,drip)	62	50	24	582	291	0
1.2.cotton.(flood,sprink,drip)	62	50	24	512	256	0
1.3.cotton.(flood,sprink,drip)	62	50	24	492	246	0
1.4.cotton.(flood,sprink,drip)	62	50	24	445	223	0
1.5.cotton.(flood,sprink,drip)	62	50	24	450	225	0
2.1.cotton.(flood,sprink,drip)	62	50	24	475	238	0
2.2.cotton.(flood,sprink,drip)	62	50	24	439	219	0
2.3*5.cotton.(flood,sprink,drip)	62	50	24	434	217	0
3.1.cotton.(flood,sprink,drip)	62	50	24	483	241	0
3.2.cotton.(flood,sprink,drip)	62	50	24	485	243	0
3.3*5.cotton.(flood,sprink,drip)	62	50	24	515	257	0
4.1.cotton.(flood,sprink,drip)	62	50	24	559	279	0
4.2.cotton.(flood,sprink,drip)	62	50	24	534	267	0
4.3.cotton.(flood,sprink,drip)	62	50	24	614	307	0
4.4*5.cotton.(flood,sprink,drip)	62	50	24	498	249	0
5.1*3.cotton.(flood,sprink,drip)	53	40	14	462	231	0
5.4.cotton.(flood,sprink,drip)	53	40	14	462	231	0
5.5.cotton.(flood,sprink,drip)	53	40	14	473	236	0
6.1*3.cotton.(flood,sprink,drip)	53	40	14	598	299	0
6.4.cotton.(flood,sprink,drip)	53	40	14	487	244	0
6.5.cotton.(flood,sprink,drip)	53	40	14	415	207	0
7.1*2.cotton.(flood,sprink,drip)	53	40	14	475	238	0
7.3.cotton.(flood,sprink,drip)	53	40	14	404	202	0
7.4*5.cotton.(flood,sprink,drip)	53	40	14	404	202	0
8.1*5.cotton.(flood,sprink,drip)	62	50	24	443	222	0
9.1*5.cotton.(flood,sprink,drip)	62	50	24	421	211	0
10.1*5.cotton.(flood,sprink,drip)	62	50	24	342	171	0
1*10.1*5.autmelon.(flood,sprink,drip)	104	54	285	0	0	0
1*10.1*5.autmelon.rain	54	0	200	0	0	0
1*10.1*5.summelon.(flood,sprink,drip)	354	0	0	0	0	0
1*10.1*5.summelon.rain	254	0	0	0	0	0
1*10.1*5.sprptt.(flood,sprink,drip,rain)	0	0	0	0	0	0
1*10.1*5.sumtmt.(flood,sprink,drip,rain)	486	456	305	0	0	0
1*10.1*3.sumegg.(flood,sprink,drip,rain)	104	170	130	0	0	0

I.3.4. physical inputs' requirements (kg/ha)

```
parameter input(rr,agz,in,c,irr)
* quantities of fertilizers and seeds costs of other physical inputs (kg per hectare)
/1*10.1*5.Nfert.wheat.(flood,sprink,drip)          400
1*10.1*5.Pfert.wheat.(flood,sprink,drip)           200
1*10.1*5.seed.wheat.(flood,sprink,drip)            350
1*10.1*5.other.wheat.(flood,sprink,drip)           4000
1*10.1.Nfert.wheat.rain                            100
1*10.2.Nfert.wheat.rain                            50
```

```
1*10.1.Pfert.wheat.rain                                50
1*10.2.Pfert.wheat.rain                                25
1*10.1*5.seed.wheat.rain                               150
1*10.1.other.wheat.rain                                3500
1*10.2.other.wheat.rain                                2600
1*10.3.other.wheat.rain                                2000
1*10.4.other.wheat.rain                                1400
1*10.5.other.wheat.rain                                1100

1*10.1*5.Nfert.barley.(flood,sprink,drip)              300
1*10.1*5.Pfert.barley.(flood,sprink,drip)              150
1*10.1*5.seed.barley.(flood,sprink,drip)               300
1*10.1*5.other.barley.(flood,sprink,drip)              3000
1*10.1.Nfert.barley.rain                               100
1*10.2.Nfert.barley.rain                               50
1*10.1.Pfert.barley.rain                               50
1*10.2.Pfert.barley.rain                               25
1*10.1*5.seed.barley.rain                              200
1*10.1.other.barley.rain                               2912
1*10.2.other.barley.rain                               2136
1*10.3.other.barley.rain                               1551
1*10.4.other.barley.rain                               1011
1*10.5.other.barley.rain                               964

1*10.1*5.Nfert.intmaiz.(flood,sprink,drip,rain)        400
1*10.1*5.Pfert.intmaiz.(flood,sprink,drip)             150
1*10.1*5.Kfert.intmaiz.(flood,sprink,drip)             0
1*10.1*5.seed.intmaiz.(flood,sprink,drip)              50
1*10.1*5.other.intmaiz.(flood,sprink,drip)             2000

1*10.1.Pfert.lentil.rain                               50
1*10.2.Pfert.lentil.rain                               25
1*10.1*5.seed.lentil.rain                              130
1*10.1.other.lentil.rain                               2093
1*10.2.other.lentil.rain                               1715
1*10.3*5.other.lentil.rain                             1162
1*10.1*5.Pfert.lentil.(flood,sprink,drip)              100
1*10.1*5.seed.lentil.(flood,sprink,drip)               150
1*10.1*5.other.lentil.(flood,sprink,drip)              2500

1*10.1*5.seed.chick.rain                               120
1*10.1.other.chick.rain                                990
1*10.2.other.chick.rain                                765
1*10.3*5.other.chick.rain                              605
1*10.1*5.Nfert.chick.(flood,sprink,drip)               50
1*10.1*5.Pfert.chick.(flood,sprink,drip)               50
1*10.1*5.seed.chick.(flood,sprink,drip)                120
1*10.1*5.other.chick.(flood,sprink,drip)               2000

1*10.1*5.Nfert.bdbean.(flood,sprink,drip)              0
1*10.1*5.Pfert.bdbean.(flood,sprink,drip)              250
1*10.1*5.Kfert.bdbean.(flood,sprink,drip)              0
1*10.1*5.seed.bdbean.(flood,sprink,drip)               150
1*10.1*5.other.bdbean.(flood,sprink,drip)              3800

1*10.1*5.Nfert.sybean.(flood,sprink,drip,rain)         100
1*10.1*5.Pfert.sybean.(flood,sprink,drip)              100
1*10.1*5.Kfert.sybean.(flood,sprink,drip)              100
1*10.1*5.seed.sybean.(flood,sprink,drip)               100
1*10.1*5.other.sybean.(flood,sprink,drip)              6150

1*10.1*5.Nfert.autsugar.(flood,sprink,drip,rain)       500
1*10.1*5.Pfert.autsugar.(flood,sprink,drip,rain)       200
1*10.1*5.Kfert.autsugar.(flood,sprink,drip,rain)       150
1*10.1*5.seed.autsugar.(flood,sprink,drip,rain)        17.5
1*10.1*5.other.autsugar.(flood,sprink,drip,rain)       2000

1*10.1*5.Nfert.winsugar.(flood,sprink,drip,rain)       500
1*10.1*5.Pfert.winsugar.(flood,sprink,drip,rain)       200
1*10.1*5.Kfert.winsugar.(flood,sprink,drip,rain)       150
1*10.1*5.seed.winsugar.(flood,sprink,drip,rain)        17.5
1*10.1*5.other.winsugar.(flood,sprink,drip,rain)       2000

1*10.1*5.Nfert.sesame.(flood,sprink,drip,rain)         100
1*10.1*5.Pfert.sesame.(flood,sprink,drip)              100
1*10.1*5.Kfert.sesame.(flood,sprink,drip)              0
1*10.1*5.seed.sesame.(flood,sprink,drip)               100
1*10.1*5.other.sesame.(flood,sprink,drip)              1150
```

```
1*10.1*5.Nfert.peanut.(flood,sprink,drip,rain)      500
1*10.1*5.Pfert.peanut.(flood,sprink,drip)           250
1*10.1*5.Kfert.peanut.(flood,sprink,drip)           100
1*10.1*5.seed.peanut.(flood,sprink,drip)            75
1*10.1*5.other.peanut.(flood,sprink,drip)           6500

1*10.1.Nfert.cumin.rain                             50
1*10.2.Nfert.cumin.rain                             25
1*10.1.Pfert.cumin.rain                             60
1*10.2.Pfert.cumin.rain                             30
1*10.3.Pfert.cumin.rain                             15
1*10.1*5.seed.cumin.rain                            37
1*10.1.other.cumin.rain                             454
1*10.2.other.cumin.rain                             427
1*10.3*5.other.cumin.rain                           250

1*10.1*5.Nfert.cumin.(flood,sprink,drip)            50
1*10.1*5.Pfert.cumin.(flood,sprink,drip)            60
1*10.1*5.seed.cumin.(flood,sprink,drip)             35
1*10.1*5.other.cumin.(flood,sprink,drip)            450

1*10.1*5.Nfert.cotton.(flood,sprink,drip)           400
1*10.1*5.Pfert.cotton.(flood,sprink,drip)           150
1*10.1*5.Kfert.cotton.(flood,sprink,drip)           50
1*10.1*5.seed.cotton.(flood,sprink,drip)            110
1*10.1*5.other.cotton.(flood,sprink,drip)           8266

1*10.1*5.Nfert.autmelon.(flood,sprink,drip,rain)    225
1*10.1*5.Pfert.autmelon.(flood,sprink,drip,rain)    170
1*10.1*5.Kfert.autmelon.(flood,sprink,drip,rain)    0
1*10.1*5.seed.autmelon.(flood,sprink,drip,rain)     10
1*10.1*5.other.autmelon.(flood,sprink,drip,rain)    14000

1*10.1*5.Nfert.summelon.(flood,sprink,drip,rain)    325
1*10.1*5.Pfert.summelon.(flood,sprink,drip,rain)    170
1*10.1*5.Kfert.summelon.(flood,sprink,drip,rain)    0
1*10.1*5.seed.summelon.(flood,sprink,drip,rain)     10
1*10.1*5.other.summelon.(flood,sprink,drip,rain)    15000

1*10.1*5.Nfert.sprptt.(flood,sprink,drip,rain)      500
1*10.1*5.Pfert.sprptt.(flood,sprink,drip,rain)      500
1*10.1*5.Kfert.sprptt.(flood,sprink,drip,rain)      250
1*10.1*5.seed.sprptt.(flood,sprink,drip,rain)       3000
1*10.1*5.other.sprptt.(flood,sprink,drip,rain)      8500

1*10.1*5.Nfert.sumtmt.(flood,sprink,drip,rain)      250
1*10.1*5.Pfert.sumtmt.(flood,sprink,drip,rain)      250
1*10.1*5.Kfert.sumtmt.(flood,sprink,drip,rain)      100
1*10.1*5.seed.sumtmt.(flood,sprink,drip,rain)       19
1*10.1*5.other.sumtmt.(flood,sprink,drip,rain)      9500

1*10.1*5.Nfert.sumegg.(flood,sprink,drip,rain)      300
1*10.1*5.Pfert.sumegg.(flood,sprink,drip,rain)      200
1*10.1*5.Kfert.sumegg.(flood,sprink,drip,rain)      50
1*10.1*5.seed.sumegg.(flood,sprink,drip,rain)       19
1*10.1*5.other.sumegg.(flood,sprink,drip,rain)      8600
        /
```

I.3.5. rental machinery costs (SP/ha)

```
table rentalmachcost(rr,agz,c,irr,t)
```

	Jan	Feb	Mar	Apr	May	Jun
1*4.1*5.wheat.(flood,sprink,drip)	0	0	0	0	0	2000
1*4.1.wheat.rain	0	0	0	0	0	1500
1*4.2.wheat.rain	0	0	0	0	0	1200
1*4.3.wheat.rain	0	0	0	0	0	600
1*4.4.wheat.rain	0	0	0	0	0	500
1*4.5.wheat.rain	0	0	0	0	0	350
5*7.3.wheat.(flood,sprink,drip)	0	0	0	0	0	3000
5*7.4.wheat.(flood,sprink,drip)	0	0	0	0	0	3100
5*7.5.wheat.(flood,sprink,drip)	0	0	0	0	0	3000

5*7.2.wheat.(flood,sprink,drip)	0	0	0	0	0	2393
5*6.1*3.wheat.rain	0	0	0	0	0	1000
5*6.4.wheat.rain	0	0	0	0	0	650
5*6.5.wheat.rain	0	0	0	0	0	50
7*10.1*2.wheat.rain	0	0	0	0	0	3086
7*10.3.wheat.rain	0	0	0	0	0	1520
7*10.4*5.wheat.rain	0	0	0	0	0	104
8.1*4.wheat.(flood,sprink,drip)	0	0	0	0	0	3091
8.5.wheat.(flood,sprink,drip)	0	0	0	0	0	3243
9.1*5.wheat.(flood,sprink,drip)	0	0	0	0	0	2629
10.1*5.wheat.(flood,sprink,drip)	0	0	0	0	0	2884
1*4.1*5.barley.(flood,sprink,drip)	0	0	0	0	2000	0
1*4.1.barley.rain	0	0	0	0	1100	0
1*4.2.barley.rain	0	0	0	0	850	0
1*4.3.barley.rain	0	0	0	0	550	0
1*4.4.barley.rain	0	0	0	0	273	0
1*4.5.barley.rain	0	0	0	0	224	0
5*7.1*5.barley.(flood,sprink,drip)	0	0	0	0	1300	0
5*6.1*3.barley.rain	0	0	0	0	402	0
5*6.4.barley.rain	0	0	0	0	155	0
5*10.5.barley.rain	0	0	0	0	146	0
7*10.1*2.barley.rain	0	0	0	0	822	0
7*10.3.barley.rain	0	0	0	0	389	0
7*10.4.barley.rain	0	0	0	0	133	0
8*10.1*5.barley.(flood,sprink,drip)	0	0	0	0	2000	0
1*10.1*5.intmaiz.(flood,sprink,drip,rain)	0	0	0	0	0	4000
1*10.1.lentil.rain	300	0	0	0	0	2135
1*10.2.lentil.rain	300	0	0	0	0	1911
1*10.3*5.lentil.rain	0	0	0	0	0	1162
1*10.1*5.lentil.(flood,sprink,drip)						
1*10.1.chick.rain	720	0	0	0	0	3168
1*10.2.chick.rain	600	0	0	0	0	1728
1*10.3*5.chick.rain	400	0	0	0	0	704
1*10.1*5.chick.(flood,sprink,drip)	3600	0	0	0	0	0
1*10.1*5.bdbean.(flood,sprink,drip,rain)	2300	0	300	300	0	0
1*10.1*5.sybean.(flood,sprink,drip,rain)	0	0	0	0	2125	0
1*10.1*5.autsugar.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1*5.winsugar.(flood,sprink,drip)	500	0	0	0	0	0
1*10.1*5.sesame.(flood,sprink,drip,rain)	0	0	0	0	0	0

1*10.1*5.peanut.(flood,sprink,drip)	3500	3500	0	0	0	0
1*10.1.cumin.rain	2500	0	0	0	0	2745
1*10.2.cumin.rain	2000	0	0	0	0	2625
1*10.3.cumin.rain	1000	0	0	0	0	1500
1*10.4*5.cumin.rain	1000	0	0	0	0	1260
1*10.1*5.cumin.(flood,sprink,drip)	3600	0	0	0	0	0
1*10.1*5.cotton.(flood,sprink,drip)	0	0	1000	1000	0	0
1*10.1*5.autmelon.(flood,sprink,drip,rain)	0	0	0	0	0	5000
1*10.1*5.summelon.(flood,sprink,drip,rain)	0	0	0	0	0	0
1*10.1*5.sprptt.(flood,sprink,drip)	3000	0	400	400	500	0
1*10.1*5.sumtmt.(flood,sprink,drip)	0	0	0	0	0	3850
1*10.1*5.sumegg.(flood,sprink,drip)	0	0	0	4550	0	700

+	Jul	Aug	Sep	Oct	Nov	Dec
1*4.1*5.wheat.(flood,sprink,drip)	0	0	0	0	3000	1000
1*4.1.wheat.rain	0	0	0	0	1500	0
1*4.2.wheat.rain	0	0	0	0	1000	0
1*4.3.wheat.rain	0	0	0	0	850	0
1*4.4.wheat.rain	0	0	0	0	750	0
1*4.5.wheat.rain	0	0	0	0	600	0
5*7.3.wheat.(flood,sprink,drip)	0	0	0	0	3000	1000
5*7.4.wheat.(flood,sprink,drip)	0	0	0	0	3000	1000
5*7.5.wheat.(flood,sprink,drip)	0	0	0	0	3000	1000
5*7.2.wheat.(flood,sprink,drip)	0	0	0	0	3000	1000
5*6.1*3.wheat.rain	0	0	0	0	850	0
5*6.4.wheat.rain	0	0	0	0	750	0
5*6.5.wheat.rain	0	0	0	0	600	0
7*10.1*2.wheat.rain	0	0	0	0	1000	0
7*10.3.wheat.rain	0	0	0	0	850	0
7*10.4*5.wheat.rain	0	0	0	0	750	0
8.1*4.wheat.(flood,sprink,drip)	0	0	0	0	2500	900
8.5.wheat.(flood,sprink,drip)	0	0	0	0	2500	900
9.1*5.wheat.(flood,sprink,drip)	0	0	0	0	2500	900
10.1*5.wheat.(flood,sprink,drip)	0	0	0	0	2500	900
1*4.1*5.barley.(flood,sprink,drip)	0	0	0	2500	900	0
1*4.1.barley.rain	0	0	0	1500	0	0
1*4.2.barley.rain	0	0	0	1000	0	0
1*4.3.barley.rain	0	0	0	850	0	0
1*4.4.barley.rain	0	0	0	750	0	0
1*4.5.barley.rain	0	0	0	600	0	0

5*7.1*5.barley.(flood,sprink,drip)	0	0	0	2000	1000	0
5*6.1*3.barley.rain	0	0	0	850	0	0
5*6.4.barley.rain	0	0	0	750	0	0
5*10.5.barley.rain	0	0	0	600	0	0
7*10.1*2.barley.rain	0	0	0	1000	0	0
7*10.3.barley.rain	0	0	0	850	0	0
7*10.4.barley.rain	0	0	0	750	0	0
8*10.1*5.barley.(flood,sprink,drip)	0	0	0	2500	900	0
1*10.1*5.intmaiz.(flood,sprink,drip,rain)	0	0	0	1000	0	0
1*10.1.lentil.rain	0	0	0	0	0	1300
1*10.2.lentil.rain	0	0	0	0	0	750
1*10.3*5.lentil.rain	0	0	0	0	0	750
1*10.1*5.lentil.(flood,sprink,drip)						
1*10.1.chick.rain	0	0	0	0	0	1100
1*10.2.chick.rain	0	0	0	0	0	800
1*10.3*5.chick.rain	0	0	0	0	0	600
1*10.1*5.chick.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1*5.bdbean.(flood,sprink,drip,rain)	0	0	0	0	0	0
1*10.1*5.sybean.(flood,sprink,drip,rain)	0	0	3600	0	0	0
1*10.1*5.autsugar.(flood,sprink,drip)	0	0	0	4500	500	0
1*10.1*5.winsugar.(flood,sprink,drip)	0	0	0	0	0	4500
1*10.1*5.sesame.(flood,sprink,drip,rain)	2700	0	0	0	0	0
1*10.1*5.peanut.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1.cumin.rain	0	0	0	0	0	1300
1*10.2.cumin.rain	0	0	0	0	0	750
1*10.3.cumin.rain	0	0	0	0	0	750
1*10.4*5.cumin.rain	0	0	0	0	0	750
1*10.1*5.cumin.(flood,sprink,drip)	0	0	0	0	0	0
1*10.1*5.cotton.(flood,sprink,drip)	0	0	0	0	2000	0
1*10.1*5.autmelon.(flood,sprink,drip,rain)	0	0	0	0	0	0
1*10.1*5.summelon.(flood,sprink,drip,rain)	5000	0	0	0	0	0
1*10.1*5.sprptt.(flood,sprink,drip)	1000	0	0	0	0	0
1*10.1*5.sumtmt.(flood,sprink,drip)	0	700	700	0	0	0

```
1*10.1*5.sumegg.(flood,sprink,drip)           700       0        0        0        0        0
```

I.3.6. Diesel requirements for pumping irrigation water (litre/ha)

```
table dieselreq(rr,c,irr,wtr,agz)
* diesel requirements by crops - irrigation technique and agro-ecological zones (litre per hectare)
* These numbers have been estimated based on water requirements
                           1          2          3          4          5
1*4.wheat.flood.riv       85          96        107        128        160
1*4.wheat.sprink.riv      77          86        96         115        144
1*4.wheat.flood.net        0          0          0          0          0
1*4.wheat.sprink.net      77          86        96         115        144
1*4.wheat.flood.wel       640        720        800        960        1200
1*4.wheat.sprink.wel      576        648        720        864        1080
5*7.wheat.flood.riv       284        284        338        400        455
5*7.wheat.sprink.riv      256        256        304        360        410
5*7.wheat.flood.net       284        284        338        400        455
5*7.wheat.sprink.net      256        256        304        360        410
5*6.wheat.flood.wel       568        568        675        800        910
5*6.wheat.sprink.wel      511        511        608        720        819
7.wheat.flood.wel         710        710        844        1000       1138
7.wheat.sprink.wel        639        639        760        900        1024
8*10.wheat.flood.riv      298        299        299        300        300
8*10.wheat.sprink.riv     268        269        269        270        270
8*10.wheat.flood.net      298        299        299        300        300
8*10.wheat.sprink.net     268        269        269        270        270
8*10.wheat.flood.wel      596        597        598        599        600
8*10.wheat.sprink.wel     536        537        538        539        540

1*4.barley.flood.riv      45          50         56        78         100
1*4.barley.sprink.riv     40          45         50        70         90
1*4.barley.flood.net       0          0          0         0          0
1*4.barley.sprink.net     40          45         50        70         90
1*4.barley.flood.wel      335        377        419        585        752
1*4.barley.sprink.wel     302        340        377        527        677
5*7.barley.flood.riv      149        149        177        244        244
5*7.barley.sprink.riv     134        134        159        219        219
5*7.barley.drip.riv       119        119        142        195        195
5*7.barley.flood.net      149        149        177        244        244
5*7.barley.sprink.net     134        134        159        219        219
5*7.barley.drip.net       119        119        142        195        195
7.barley.flood.wel        372        372        442        609        713
7.barley.sprink.wel       335        335        398        549        642
8*10.barley.flood.riv     156        157        157        183        188
8*10.barley.sprink.riv    141        141        141        165        169
8*10.barley.flood.net     156        157        157        183        188
8*10.barley.sprink.net    141        141        141        165        169
8*10.barley.flood.wel     312        313        313        365        376
8*10.barley.sprink.wel    281        282        282        329        338

1*4.intmaiz.flood.riv     620        620        620        620        620
1*4.intmaiz.sprink.riv    558        558        558        558        558
1*4.intmaiz.flood.net      0          0          0          0          0
1*4.intmaiz.sprink.net    558        558        558        558        558
1*4.intmaiz.flood.wel     1431       1431      1431       1431       1431
1*4.intmaiz.sprink.wel    1288       1288      1288       1288       1288
5*10.intmaiz.flood.riv    382        382        382        382        382
5*10.intmaiz.sprink.riv   343        343        343        343        343
5*10.intmaiz.flood.net    382        382        382        382        382
5*10.intmaiz.sprink.net   343        343        343        343        343
5*10.intmaiz.flood.wel    763        763        763        763        763
5*10.intmaiz.sprink.wel   687        687        687        687        687

$ontext
8*10.intmaiz.flood.riv    203        203        203        203        203
8*10.intmaiz.sprink.riv   183        183        183        183        183
8*10.intmaiz.flood.net    203        203        203        203        203
8*10.intmaiz.sprink.net   183        183        183        183        183
8*10.intmaiz.flood.wel    405        405        405        405        405
8*10.intmaiz.sprink.wel   365        365        365        365        365
$offtext

1*4.lentil.flood.riv      21          24         30         43        46
1*4.lentil.sprink.riv     18          22         27         39        42
1*4.lentil.flood.net       0          0          0          0         0
1*4.lentil.sprink.net     18          22         27         39        42
```

1*4.lentil.flood.wel	154	180	224	321	347
1*4.lentil.sprink.wel	139	162	202	289	312
5*7.lentil.flood.riv	68	71	95	134	131
5*7.lentil.sprink.riv	62	64	85	120	118
5*7.lentil.flood.net	68	71	95	134	131
5*7.lentil.sprink.net	62	64	85	120	118
5*6.lentil.flood.wel	137	142	189	267	263
5*6.lentil.sprink.wel	123	128	170	241	237
7.lentil.flood.wel	171	177	237	334	329
7.lentil.sprink.wel	154	160	213	301	296
8*10.lentil.flood.riv	72	75	84	100	87
8*10.lentil.sprink.riv	65	67	76	90	78
8*10.lentil.flood.net	72	75	84	100	87
8*10.lentil.sprink.net	65	67	76	90	78
8*10.lentil.flood.wel	143	149	168	200	173
8*10.lentil.sprink.wel	129	134	151	180	156
1*4.chick.flood.riv	21	24	30	43	46
1*4.chick.sprink.riv	18	22	27	39	42
1*4.chick.flood.net	0	0	0	0	0
1*4.chick.sprink.net	18	22	27	39	42
1*4.chick.flood.wel	154	180	224	321	347
1*4.chick.sprink.wel	139	162	202	289	312
5*7.chick.flood.riv	68	71	95	134	131
5*7.chick.sprink.riv	62	64	85	120	118
5*7.chick.flood.net	68	71	95	134	131
5*7.chick.sprink.net	62	64	85	120	118
5*6.chick.flood.wel	137	142	189	267	263
5*6.chick.sprink.wel	123	128	170	241	237
7.chick.flood.wel	171	177	237	334	329
7.chick.sprink.wel	154	160	213	301	296
8*10.chick.flood.riv	72	75	84	100	87
8*10.chick.sprink.riv	65	67	76	90	78
8*10.chick.flood.net	72	75	84	100	87
8*10.chick.sprink.net	65	67	76	90	78
8*10.chick.flood.wel	143	149	168	200	173
8*10.chick.sprink.wel	129	134	151	180	156
1*4.bdbean.flood.riv	66	66	76	76	76
1*4.bdbean.sprink.riv	59	59	69	69	69
1*4.bdbean.flood.net	0	0	0	0	0
1*4.bdbean.sprink.net	59	59	69	69	69
1*4.bdbean.flood.wel	492	492	572	572	572
1*4.bdbean.sprink.wel	443	443	515	515	515
5*7.bdbean.flood.riv	218	194	242	238	217
5*7.bdbean.sprink.riv	197	175	217	215	195
5*7.bdbean.flood.net	218	194	242	238	217
5*7.bdbean.sprink.net	197	175	217	215	195
5*6.bdbean.flood.wel	437	388	483	477	434
5*6.bdbean.sprink.wel	393	350	435	429	391
7.bdbean.flood.wel	546	486	604	596	542
7.bdbean.sprink.wel	492	437	543	536	488
8*10.bdbean.flood.riv	229	204	214	179	143
8*10.bdbean.sprink.riv	207	184	193	161	129
8*10.bdbean.flood.net	229	204	214	179	143
8*10.bdbean.sprink.net	207	184	193	161	129
8*10.bdbean.flood.wel	458	408	428	357	286
8*10.bdbean.sprink.wel	413	367	385	321	257
1*4.sybean.flood.riv	545	545	545	545	545
1*4.sybean.sprink.riv	491	491	491	491	491
1*4.sybean.flood.net	0	0	0	0	0
1*4.sybean.sprink.net	491	491	491	491	491
1*4.sybean.flood.wel	1258	1258	1258	1258	1258
1*4.sybean.sprink.wel	1132	1132	1132	1132	1132
5*7.sybean.flood.riv	335	335	335	335	335
5*7.sybean.sprink.riv	302	302	302	302	302
5*7.sybean.flood.net	335	335	335	335	335
5*7.sybean.sprink.net	302	302	302	302	302
5*6.sybean.flood.wel	671	671	671	671	671
5*6.sybean.sprink.wel	604	604	604	604	604
7.sybean.flood.wel	579	579	579	579	579
7.sybean.sprink.wel	521	521	521	521	521
8*10.sybean.flood.riv	178	178	178	178	178
8*10.sybean.sprink.riv	161	161	161	161	161
8*10.sybean.flood.net	178	178	178	178	178
8*10.sybean.sprink.net	161	161	161	161	161
8*10.sybean.flood.wel	356	356	356	356	356

8*10.sybean.sprink.wel	321	321	321	321	321
1*4.autsugar.flood.riv	340	340	405	450	487
1*4.autsugar.sprink.riv	306	306	364	405	439
1*4.autsugar.flood.net	0	0	0	0	0
1*4.autsugar.sprink.net	306	306	364	405	439
1*4.autsugar.flood.wel	983	983	1170	1300	1408
1*4.autsugar.sprink.wel	885	885	1053	1170	1267
5*7.autsugar.flood.riv	340	340	405	450	487
5*7.autsugar.sprink.riv	306	306	364	405	439
5*7.autsugar.flood.net	340	340	405	450	487
5*7.autsugar.sprink.net	306	306	364	405	439
5*6.autsugar.flood.wel	983	983	1170	1300	1408
5*6.autsugar.sprink.wel	885	885	1053	1170	1267
7.autsugar.flood.wel	983	983	1170	1300	1408
7.autsugar.sprink.wel	885	885	1053	1170	1267
8*10.autsugar.flood.riv	139	139	139	139	139
8*10.autsugar.sprink.riv	125	125	125	125	125
8*10.autsugar.flood.net	139	139	139	139	139
8*10.autsugar.sprink.net	125	125	125	125	125
8*10.autsugar.flood.wel	277	277	277	277	277
8*10.autsugar.sprink.wel	249	249	249	249	249
1*4.winsugar.flood.riv	340	340	405	450	487
1*4.winsugar.sprink.riv	306	306	364	405	439
1*4.winsugar.flood.net	0	0	0	0	0
1*4.winsugar.sprink.net	306	306	364	405	439
1*4.winsugar.flood.wel	983	983	1170	1300	1408
1*4.winsugar.sprink.wel	885	885	1053	1170	1267
5*7.winsugar.flood.riv	340	340	405	450	487
5*7.winsugar.sprink.riv	306	306	364	405	439
5*7.winsugar.flood.net	340	340	405	450	487
5*7.winsugar.sprink.net	306	306	364	405	439
5*6.winsugar.flood.wel	983	983	1170	1300	1408
5*6.winsugar.sprink.wel	885	885	1053	1170	1267
7.winsugar.flood.wel	983	983	1170	1300	1408
7.winsugar.sprink.wel	885	885	1053	1170	1267
8*10.winsugar.flood.riv	139	139	139	139	139
8*10.winsugar.sprink.riv	125	125	125	125	125
8*10.winsugar.flood.net	139	139	139	139	139
8*10.winsugar.sprink.net	125	125	125	125	125
8*10.winsugar.flood.wel	277	277	277	277	277
8*10.winsugar.sprink.wel	249	249	249	249	249
1*4.sesame.flood.riv	780	780	780	780	780
1*4.sesame.sprink.riv	702	702	702	702	702
1*4.sesame.flood.net	0	0	0	0	0
1*4.sesame.sprink.net	702	702	702	702	702
1*4.sesame.flood.wel	1800	1800	1800	1800	1800
1*4.sesame.sprink.wel	1620	1620	1620	1620	1620
5*10.sesame.flood.riv	480	480	480	480	480
5*10.sesame.sprink.riv	432	432	432	432	432
5*10.sesame.flood.net	480	480	480	480	480
5*10.sesame.sprink.net	432	432	432	432	432
5*6.sesame.flood.wel	960	960	960	960	960
5*6.sesame.sprink.wel	864	864	864	864	864
7*10.sesame.flood.wel	828	828	828	828	828
7*10.sesame.sprink.wel	746	746	746	746	746
1*4.peanut.flood.riv	94	113	122	141	141
1*4.peanut.sprink.riv	85	102	110	127	127
1*4.peanut.drip.riv	75	90	98	113	113
1*4.peanut.flood.net	0	0	0	0	0
1*4.peanut.sprink.net	85	102	110	127	127
1*4.peanut.drip.net	75	90	98	113	113
1*4.peanut.flood.wel	706	847	918	1059	1059
1*4.peanut.sprink.wel	635	762	826	953	953
1*4.peanut.drip.wel	565	678	734	847	847
5*7.peanut.flood.riv	313	334	387	441	402
5*7.peanut.sprink.riv	282	301	349	397	361
5*7.peanut.drip.riv	251	267	310	353	321
5*7.peanut.flood.net	313	334	387	441	402
5*7.peanut.sprink.net	282	301	349	397	361
5*7.peanut.drip.net	251	267	310	353	321
5*6.peanut.flood.wel	627	669	775	882	803
5*6.peanut.sprink.wel	564	602	697	794	723
5*6.peanut.drip.wel	501	535	620	706	643
7.peanut.flood.wel	783	836	969	1103	1004

7.peanut.sprink.wel	705	752	872	993	904
7.peanut.drip.wel	627	669	775	882	803
8*10.peanut.flood.riv	329	352	343	331	265
8*10.peanut.sprink.riv	296	316	309	298	239
8*10.peanut.drip.riv	263	281	275	265	212
8*10.peanut.flood.net	329	352	343	331	265
8*10.peanut.sprink.net	296	316	309	298	239
8*10.peanut.drip.net	263	281	275	265	212
8*10.peanut.flood.wel	657	703	686	661	529
8*10.peanut.sprink.wel	592	632	617	595	477
8*10.peanut.drip.wel	526	562	549	529	424
1*4.cumin.flood.riv	22	27	29	33	36
1*4.cumin.sprink.riv	20	24	26	30	32
1*4.cumin.flood.net	0	0	0	0	0
1*4.cumin.sprink.net	20	24	26	30	32
1*4.cumin.flood.wel	167	200	217	250	270
1*4.cumin.sprink.wel	150	180	195	225	243
5*7.cumin.flood.riv	74	79	92	104	102
5*7.cumin.sprink.riv	67	71	82	94	92
5*7.cumin.flood.net	74	79	92	104	102
5*7.cumin.sprink.net	67	71	82	94	92
5*6.cumin.flood.wel	148	158	183	209	204
5*6.cumin.sprink.wel	133	142	165	188	184
7.cumin.flood.wel	185	198	229	261	256
7.cumin.sprink.wel	167	178	206	235	230
8*10.cumin.flood.riv	78	83	81	78	68
8*10.cumin.sprink.riv	70	75	73	71	61
8*10.cumin.flood.net	78	83	81	78	68
8*10.cumin.sprink.net	70	75	73	71	61
8*10.cumin.flood.wel	155	166	162	156	135
8*10.cumin.sprink.wel	140	149	146	141	121
1*4.cotton.flood.riv	1300	1300	1300	1300	1300
1*4.cotton.sprink.riv	1170	1170	1170	1170	1170
1*4.cotton.drip.riv	1040	1040	1040	1040	1040
1*4.cotton.flood.net	0	0	0	0	0
1*4.cotton.sprink.net	1170	1170	1170	1170	1170
1*4.cotton.drip.net	1040	1040	1040	1040	1040
1*4.cotton.flood.wel	3000	3000	3000	3000	3000
1*4.cotton.sprink.wel	2700	2700	2700	2700	2700
1*4.cotton.drip.wel	2400	2400	2400	2400	2400
5*10.cotton.flood.riv	800	800	800	800	800
5*10.cotton.sprink.riv	720	720	720	720	720
5*10.cotton.drip.riv	640	640	640	640	640
5*10.cotton.flood.net	800	800	800	800	800
5*10.cotton.sprink.net	720	720	720	720	720
5*10.cotton.drip.net	640	640	640	640	640
5*6.cotton.flood.wel	1600	1600	1600	1600	1600
5*6.cotton.sprink.wel	1440	1440	1440	1440	1440
5*6.cotton.drip.wel	1280	1280	1280	1280	1280
7*10.cotton.flood.wel	1380	1380	1380	1380	1380
7*10.cotton.sprink.wel	1242	1242	1242	1242	1242
7*10.cotton.drip.wel	1104	1104	1104	1104	1104
1*4.autmelon.flood.riv	421	421	421	421	421
1*4.autmelon.sprink.riv	379	379	379	379	379
1*4.autmelon.drip.riv	336	336	336	336	336
1*4.autmelon.flood.net	0	0	0	0	0
1*4.autmelon.sprink.net	379	379	379	379	379
1*4.autmelon.drip.net	336	336	336	336	336
1*4.autmelon.flood.wel	971	971	971	971	971
1*4.autmelon.sprink.wel	873	873	873	873	873
1*4.autmelon.drip.wel	776	776	776	776	776
5*7.autmelon.flood.riv	259	259	259	259	259
5*7.autmelon.sprink.riv	233	233	233	233	233
5*7.autmelon.drip.riv	207	207	207	207	207
5*7.autmelon.flood.net	259	259	259	259	259
5*7.autmelon.sprink.net	233	233	233	233	233
5*7.autmelon.drip.net	207	207	207	207	207
5*6.autmelon.flood.wel	518	518	518	518	518
5*6.autmelon.sprink.wel	466	466	466	466	466
5*6.autmelon.drip.wel	414	414	414	414	414
7.autmelon.flood.wel	446	446	446	446	446
7.autmelon.sprink.wel	402	402	402	402	402
7.autmelon.drip.wel	357	357	357	357	357
8*10.autmelon.flood.riv	138	138	138	138	138
8*10.autmelon.sprink.riv	124	124	124	124	124

8*10.autmelon.drip.riv	110	110	110	110	110
8*10.autmelon.flood.net	138	138	138	138	138
8*10.autmelon.sprink.net	124	124	124	124	124
8*10.autmelon.drip.net	110	110	110	110	110
8*10.autmelon.flood.wel	275	275	275	275	275
8*10.autmelon.sprink.wel	247	247	247	247	247
8*10.autmelon.drip.wel	220	220	220	220	220
1*4.summelon.flood.riv	571	571	571	571	571
1*4.summelon.sprink.riv	514	514	514	514	514
1*4.summelon.drip.riv	457	457	457	457	457
1*4.summelon.flood.net	0	0	0	0	0
1*4.summelon.sprink.net	514	514	514	514	514
1*4.summelon.drip.net	457	457	457	457	457
1*4.summelon.flood.wel	1317	1317	1317	1317	1317
1*4.summelon.sprink.wel	1185	1185	1185	1185	1185
1*4.summelon.drip.wel	1054	1054	1054	1054	1054
5*7.summelon.flood.riv	351	351	351	351	351
5*7.summelon.sprink.riv	316	316	316	316	316
5*7.summelon.drip.riv	281	281	281	281	281
5*7.summelon.flood.net	351	351	351	351	351
5*7.summelon.sprink.net	316	316	316	316	316
5*7.summelon.drip.net	281	281	281	281	281
5*6.summelon.flood.wel	702	702	702	702	702
5*6.summelon.sprink.wel	632	632	632	632	632
5*6.summelon.drip.wel	562	562	562	562	562
7.summelon.flood.wel	606	606	606	606	606
7.summelon.sprink.wel	545	545	545	545	545
7.summelon.drip.wel	485	485	485	485	485
8*10.summelon.flood.riv	187	187	187	187	187
8*10.summelon.sprink.riv	168	168	168	168	168
8*10.summelon.drip.riv	150	150	150	150	150
8*10.summelon.flood.net	187	187	187	187	187
8*10.summelon.sprink.net	168	168	168	168	168
8*10.summelon.drip.net	150	150	150	150	150
8*10.summelon.flood.wel	373	373	373	373	373
8*10.summelon.sprink.wel	336	336	336	336	336
8*10.summelon.drip.wel	299	299	299	299	299
1*4.sprptt.flood.riv	639	639	639	639	639
1*4.sprptt.sprink.riv	575	575	575	575	575
1*4.sprptt.drip.riv	511	511	511	511	511
1*4.sprptt.flood.net	0	0	0	0	0
1*4.sprptt.sprink.net	575	575	575	575	575
1*4.sprptt.drip.net	511	511	511	511	511
1*4.sprptt.flood.wel	1475	1475	1475	1475	1475
1*4.sprptt.sprink.wel	1327	1327	1327	1327	1327
1*4.sprptt.drip.wel	1180	1180	1180	1180	1180
5*7.sprptt.flood.riv	393	393	393	393	393
5*7.sprptt.sprink.riv	354	354	354	354	354
5*7.sprptt.drip.riv	315	315	315	315	315
5*7.sprptt.flood.net	393	393	393	393	393
5*7.sprptt.sprink.net	354	354	354	354	354
5*7.sprptt.drip.net	315	315	315	315	315
5*6.sprptt.flood.wel	787	787	787	787	787
5*6.sprptt.sprink.wel	708	708	708	708	708
5*6.sprptt.drip.wel	629	629	629	629	629
7.sprptt.flood.wel	678	678	678	678	678
7.sprptt.sprink.wel	611	611	611	611	611
7.sprptt.drip.wel	543	543	543	543	543
8*10.sprptt.flood.riv	209	209	209	209	209
8*10.sprptt.sprink.riv	188	188	188	188	188
8*10.sprptt.drip.riv	167	167	167	167	167
8*10.sprptt.flood.net	209	209	209	209	209
8*10.sprptt.sprink.net	188	188	188	188	188
8*10.sprptt.drip.net	167	167	167	167	167
8*10.sprptt.flood.wel	418	418	418	418	418
8*10.sprptt.sprink.wel	376	376	376	376	376
8*10.sprptt.drip.wel	334	334	334	334	334
1*4.sumtmt.flood.riv	615	615	615	615	615
1*4.sumtmt.drip.riv	492	492	492	492	492
1*4.sumtmt.flood.net	0	0	0	0	0
1*4.sumtmt.drip.net	492	492	492	492	492
1*4.sumtmt.flood.wel	1418	1418	1418	1418	1418
1*4.sumtmt.drip.wel	1135	1135	1135	1135	1135
5*7.sumtmt.flood.riv	378	378	378	378	378
5*7.sumtmt.drip.riv	303	303	303	303	303

5*7.sumtmt.flood.net	378	378	378	378	378
5*7.sumtmt.drip.net	303	303	303	303	303
5*6.sumtmt.flood.wel	756	756	756	756	756
5*6.sumtmt.drip.wel	605	605	605	605	605
7.sumtmt.flood.wel	652	652	652	652	652
7.sumtmt.drip.wel	522	522	522	522	522
8*10.sumtmt.flood.riv	201	201	201	201	201
8*10.sumtmt.drip.riv	161	161	161	161	161
8*10.sumtmt.flood.net	201	201	201	201	201
8*10.sumtmt.drip.net	161	161	161	161	161
8*10.sumtmt.flood.wel	402	402	402	402	402
8*10.sumtmt.drip.wel	321	321	321	321	321
1*4.sumegg.flood.riv	558	558	558	558	558
1*4.sumegg.drip.riv	446	446	446	446	446
1*4.sumegg.flood.net	0	0	0	0	0
1*4.sumegg.drip.net	446	446	446	446	446
1*4.sumegg.flood.wel	1288	1288	1288	1288	1288
1*4.sumegg.drip.wel	1030	1030	1030	1030	1030
5*7.sumegg.flood.riv	343	343	343	343	343
5*7.sumegg.drip.riv	275	275	275	275	275
5*7.sumegg.flood.net	343	343	343	343	343
5*7.sumegg.drip.net	275	275	275	275	275
5*6.sumegg.flood.wel	687	687	687	687	687
5*6.sumegg.drip.wel	549	549	549	549	549
7.sumegg.flood.wel	592	592	592	592	592
7.sumegg.drip.wel	474	474	474	474	474
8*10.sumegg.flood.riv	183	183	183	183	183
8*10.sumegg.drip.riv	146	146	146	146	146
8*10.sumegg.flood.net	183	183	183	183	183
8*10.sumegg.drip.net	146	146	146	146	146
8*10.sumegg.flood.wel	365	365	365	365	365
8*10.sumegg.drip.wel	292	292	292	292	292

I.4. data of parameters differentiated at farm typology level

I.4.1 – farm fixed factors

```
* Al-Hassakeh mantikas (rr) from 1 to 4
* Al-Rakka mantikas (rr) from 5 to 7
* Der-ez-Zor mantikas (rr) from 8 to 10
* 1 = Al-Hassakeh
* 2 = Kameshli
* 3 = Al Malkiyeh
* 4 = Ras Elein
* 5 = Al-Rakka
* 6 = Al-Thawra
* 7 = Tal Abiad
* 8 = Deir-Ezzour
* 9 = Al-Mayadeen
* 10 = Bokmal
* data in this table are given by representative farming system where;
* cash is the availbility of cash (SP)
* land is the availability of land (farm size per ha)
* sprink is a dummy that represents the availability of sprinkler irrigation. it takes zero if it is
* absent
* drip is a dummy that represents the availability of drip irrigation. it takes zero if it is absent
* number represents the number of farms represented by each farming system
* agz represents the agro-climatic zone where the farming system is located
* river is a dummy that takes the value of one if the irrigation source is a river, zero otherwise
* net is a dummy that takes the value of one if the irrigation source is a public canal, zero
* otherwise
* well is a dummy that takes the value of one if the irrigation source is a private well, zero
* otherwise
* cottonls represents the maximum area that each farming system can cultivate with cotto imposed by
* the licensing system
* autsugls represents the maximum area that each farming system can cultivate with automn sugarbeet
* imposed by the licensing system
* winsugls represents the maximum area that each farming system can cultivate with winter sugarbeet
* imposed by the licensing system
* barlreq represents the minimum area that each farming system must grow under barley in order to
* feed the sheep to avoid buying feed from the market
```

	cash	land	sprink	drip	number	agz	river
1.1	1500000	15.56	0	0	90	1	0
1.2	1500000	17.63	0	0	3319	2	0
1.3	500000	6.76	0	0	1542	3	0
1.4	1000000	9.94	0	0	2347	4	0
1.5	600000	5.61	0	0	3937	5	0
1.6	1500000	17.66	1	0	180	2	0
1.7	600000	8.26	1	0	32	3	0
1.8	1500000	17.61	0	0	205	2	1
1.9	200000	5.82	0	0	653	3	1
1.10	400000	10.84	0	0	495	4	1
1.11	100000	4.80	0	0	1946	5	1
1.12	1300000	18.07	0	0	99	2	0
1.13	100000	5.13	0	0	280	3	0

1.14	500000	11.20	0	0	672	4	0
1.15	400000	5.13	0	1	1065	3	0
2.1	1500000	13.92	0	0	4734	1	0
2.2	2000000	17.72	0	0	815	2	0
2.3	2000000	16.34	0	0	330	3	0
2.4	1300000	12.77	1	0	250	1	0
2.5	1800000	17.81	1	0	192	2	0
3.1	1500000	13.78	0	0	997	1	0
3.2	600000	4.76	0	0	184	3	0
3.3	1300000	13.87	0	1	353	1	0
3.4	1500000	11.86	0	1	166	2	0
3.5	1300000	14.12	1	1	761	1	0
3.6	1200000	13.46	1	0	760	1	0
3.7	1500000	11.86	1	0	28	2	0
3.8	600000	4.76	1	0	10	3	0
3.9	1200000	14.37	0	0	420	1	1
3.10	1200000	14.37	0	0	15	1	0
4.1	2500000	24.53	0	0	3152	2	0
4.2	1500000	13.63	0	0	78	3	0
4.3	1800000	17.92	0	0	36	4	0
4.4	3000000	27.04	0	1	222	1	0
4.5	3000000	27.04	1	0	22	1	0
4.6	2500000	24.52	1	0	132	2	0
4.7	1500000	18.13	0	0	1845	1	1
4.8	1500000	14.60	0	0	1290	2	1
4.9	2000000	24.15	0	0	89	2	0
5.1	400000	4.78	0	0	64	3	0
5.2	400000	4.63	0	0	1960	4	0
5.3	450000	5.55	0	0	1975	5	0
5.4	250000	4.78	0	0	35	3	1
5.5	200000	3.72	0	0	2122	4	1
5.6	280000	5.64	0	0	4145	5	1
5.7	220000	4.78	0	0	13	3	0
5.8	200000	4.24	0	0	10546	4	0
5.9	260000	5.19	0	0	3390	5	0
6.1	500000	6.02	0	0	25	3	0
6.2	260000	3.90	0	0	230	4	0
6.3	220000	3.33	0	0	2703	5	0
6.4	350000	6.02	0	0	236	3	1
6.5	150000	3.90	0	0	420	4	1
6.6	150000	3.49	0	0	3557	5	1
6.7	300000	6.02	0	0	155	3	0
6.8	250000	5.44	0	0	1010	5	0
7.1	1000000	10.11	0	0	3596	2	0
7.2	750000	9.24	0	0	775	3	0
7.3	500000	8.47	0	0	85	4	0
7.4	1000000	10.17	0	0	986	2	1

7.5	800000	9.25	0	0	62	3	1
7.6	900000	9.95	0	0	367	2	0
7.7	800000	9.24	0	0	10	3	0
8.1	150000	2.46	0	0	2974	4	0
8.2	150000	1.86	0	0	8625	5	0
8.3	150000	2.16	0	0	21462	5	1
9.1	150000	2.02	0	0	22728	5	1
10.1	150000	2.12	0	0	155	5	0
10.2	100000	2.04	0	0	15304	5	1

+	punet	pwell	cottonls	autsugls	winsugls	barlreq	rac
1.1	0	1	3.33	0.00	0.00	0.00	0.0025
1.2	0	1	3.26	0.00	0.00	0.00	0.0025
1.3	0	1	0.85	0.00	0.00	0.86	0.0050
1.4	0	1	0.62	0.00	0.00	1.72	0.0040
1.5	0	1	0.39	0.00	0.00	0.80	0.0045
1.6	0	1	3.27	0.00	0.00	0.00	0.0020
1.7	0	1	1.13	0.00	0.00	0.47	0.0035
1.8	0	0	3.36	0.00	0.00	0.00	0.0020
1.9	0	0	0.82	0.00	0.00	0.48	0.0050
1.10	0	0	1.04	0.00	0.00	1.74	0.0025
1.11	0	0	0.45	0.00	0.00	0.65	0.0045
1.12	1	0	3.44	0.00	0.00	0.00	0.0020
1.13	1	0	0.82	0.00	0.00	0.12	0.0040
1.14	1	0	1.28	0.00	0.00	1.19	0.0035
1.15	0	1	0.82	0.00	0.00	0.12	0.0040
2.1	0	1	3.93	0.00	0.00	0.00	0.0020
2.2	0	1	4.02	0.00	0.00	0.00	0.0020
2.3	0	1	4.20	0.00	0.00	0.00	0.0025
2.4	0	1	2.79	0.00	0.00	0.00	0.0015
2.5	0	1	4.03	0.00	0.00	0.00	0.0025
3.1	0	1	3.24	0.00	0.00	0.00	0.0025
3.2	0	1	1.90	0.00	0.00	0.00	0.0050
3.3	0	1	3.15	0.00	0.00	0.00	0.0030
3.4	0	1	5.11	0.00	0.00	0.00	0.0030
3.5	0	1	3.75	0.00	0.00	0.00	0.0025
3.6	0	1	2.65	0.00	0.00	0.00	0.0030
3.7	0	1	4.11	0.00	0.00	0.00	0.0035
3.8	0	1	1.90	0.00	0.00	0.00	0.0040
3.9	0	0	3.52	0.00	0.00	0.00	0.0025
3.10	1	0	3.52	0.00	0.00	0.00	0.0030
4.1	0	1	4.68	0.00	0.00	0.21	0.0010
4.2	0	1	1.32	0.00	0.00	0.00	0.0030
4.3	0	1	2.50	0.00	0.00	0.00	0.0020
4.4	0	1	6.76	0.00	0.00	0.04	0.0020
4.5	0	1	6.76	0.00	0.00	0.06	0.0020
4.6	0	1	4.67	0.00	0.00	0.21	0.0015
4.7	0	0	3.81	0.00	0.00	0.00	0.0020

4.8	**0**	**0**	**3.92**	**0.00**	**0.00**	**0.03**	**0.0020**
4.9	**1**	**0**	**4.22**	**0.00**	**0.00**	**0.25**	**0.0025**
5.1	**0**	**1**	**1.53**	**0.00**	**0.00**	**0.00**	**0.0040**
5.2	**0**	**1**	**1.31**	**0.10**	**0.00**	**0.00**	**0.0050**
5.3	**0**	**1**	**1.58**	**0.15**	**0.00**	**0.03**	**0.0030**
5.4	**0**	**0**	**1.53**	**0.00**	**0.00**	**0.00**	**0.0060**
5.5	**0**	**0**	**1.71**	**0.08**	**0.00**	**0.00**	**0.0060**
5.6	**0**	**0**	**1.74**	**0.15**	**0.00**	**0.01**	**0.0055**
5.7	**1**	**0**	**1.53**	**0.00**	**0.00**	**0.00**	**0.0050**
5.8	**1**	**0**	**1.40**	**0.10**	**0.00**	**0.00**	**0.0055**
5.9	**1**	**0**	**1.56**	**0.15**	**0.00**	**0.03**	**0.0050**
6.1	**0**	**1**	**2.38**	**0.00**	**0.00**	**0.00**	**0.0050**
6.2	**0**	**1**	**0.69**	**0.00**	**0.00**	**0.05**	**0.0050**
6.3	**0**	**1**	**0.42**	**0.10**	**0.00**	**0.26**	**0.0050**
6.4	**0**	**0**	**2.38**	**0.00**	**0.00**	**0.00**	**0.0060**
6.5	**0**	**0**	**0.69**	**0.00**	**0.00**	**0.05**	**0.0070**
6.6	**0**	**0**	**0.40**	**0.06**	**0.00**	**0.12**	**0.0045**
6.7	**1**	**0**	**2.38**	**0.00**	**0.00**	**0.00**	**0.0070**
6.8	**1**	**0**	**1.07**	**0.03**	**0.00**	**0.12**	**0.0030**
7.1	**0**	**1**	**3.23**	**0.00**	**0.35**	**0.05**	**0.0020**
7.2	**0**	**1**	**2.28**	**0.00**	**0.00**	**1.12**	**0.0050**
7.3	**0**	**1**	**0.00**	**0.00**	**0.00**	**5.47**	**0.0050**
7.4	**0**	**0**	**3.46**	**0.00**	**0.25**	**0.08**	**0.0035**
7.5	**0**	**0**	**2.39**	**0.00**	**0.00**	**0.00**	**0.0050**
7.6	**1**	**0**	**3.69**	**0.00**	**0.25**	**0.00**	**0.0040**
7.7	**1**	**0**	**2.10**	**0.00**	**0.00**	**3.05**	**0.0035**
8.1	**0**	**1**	**0.63**	**0.09**	**0.00**	**0.01**	**0.0010**
8.2	**0**	**1**	**0.19**	**0.05**	**0.00**	**0.01**	**0.0025**
8.3	**0**	**0**	**0.43**	**0.06**	**0.00**	**0.01**	**0.0010**
9.1	**0**	**0**	**0.21**	**0.04**	**0.00**	**0.00**	**0.0025**
10.1	**0**	**1**	**0.60**	**0.08**	**0.00**	**0.01**	**0.0025**
10.2	**0**	**0**	**0.49**	**0.08**	**0.00**	**0.01**	**0.0040**

;

I.4.2. irrigation water availability (cubic meter)

table wateravail(rr,fff,t)

* irrigation water availability of individual farming systems

	Jan	Feb	Mar	Apr	May	Jun
1.1	25204	25204	25204	25204	25204	25204
1.2	30781	30781	30781	30781	30781	30781
1.3	12996	12996	12996	12996	12996	12996
1.4	22010	22010	22010	22010	22010	22010
1.5	16005	16005	16005	16005	16005	16005
1.6	28253	28253	28253	28253	28253	28253
1.7	14277	14277	14277	14277	14277	14277
1.8	0	0	13831	25148	33170	30587
1.9	0	0	5128	8623	11314	9657
1.10	0	1284	13791	21173	27579	21157

1.11	0	651	6670	10341	13470	10489
1.12	0	0	14200	25824	34059	31416
1.13	0	0	4424	7766	10717	9591
1.14	0	942	14451	22871	29821	23869
1.15	9895	9895	9895	9895	9895	9895
2.1	23270	23270	23270	23270	23270	23970
2.2	30583	30583	30583	30583	30583	30583
2.3	32597	32597	32597	32597	32597	32597
2.4	18490	18490	18490	18490	18490	18490
2.5	30617	30617	30617	30617	30617	30617
3.1	22150	22150	22150	22150	22150	22150
3.2	10199	10199	10199	10199	10199	10199
3.3	21150	21150	21150	21150	21150	21150
3.4	21467	21467	21467	21467	21467	21467
3.5	20279	20279	20279	20279	20279	20279
3.6	19411	19411	19411	19411	19411	19411
3.7	21112	21112	21112	21112	21112	21112
3.8	9180	9180	9180	9180	9180	9180
3.9	0	0	10806	18782	24938	24208
3.10	0	0	8731	17690	23770	23610
4.1	44084	44084	44084	44084	44084	44084
4.2	27474	27474	27474	27474	27474	27474
4.3	42747	42747	42747	42747	42747	42747
4.4	41125	41125	41125	41125	41125	41125
4.5	39360	39360	39360	39360	39360	39560
4.6	39672	39672	39672	39672	39672	39672
4.7	29022	29022	29022	29022	29022	29022
4.8	25660	25660	25660	25660	25950	25950
4.9	0	0	18418	32978	43413	39570
5.1	12753	12753	12753	12753	12753	12753
5.2	15351	15351	15351	15351	15351	15351
5.3	19316	19316	19316	19316	19316	19316
5.4	0	149	4790	10818	12625	14613
5.5	0	1954	10995	16080	19567	20679
5.6	1011	2614	8354	17408	19920	22189
5.7	0	149	4790	10818	12625	16383
5.8	0	1009	5843	10963	13781	16746
5.9	942	2411	7641	15723	17758	19877
6.1	21056	21056	21056	21056	21056	21056
6.2	12163	12163	12163	12163	12163	12163
6.3	10470	10470	10470	10470	10470	10470
6.4	0	166	5358	13852	16296	21056
6.5	0	1609	9055	12296	14964	14597
6.6	1110	2779	8937	12939	14206	11015
6.7	0	166	5358	13852	16296	21056
6.8	1485	3556	11771	19741	21932	16893
7.1	25931	25931	25931	25931	25931	25931

7.2	24573	24573	24573	24573	24573	24573
7.3	17509	17509	17509	17509	17509	17509
7.4	0	244	7685	22764	27941	27028
7.5	0	363	10089	20707	23984	26612
7.6	0	708	7482	22968	29136	27649
7.7	0	1345	10935	20534	23175	20543
8.1	6562	6562	6562	6562	6562	6562
8.2	5630	5566	5566	5566	5566	5566
8.3	166	1736	4180	6454	7676	6901
9.1	120	9536	22920	32283	36412	28164
10.1	7504	7504	7504	7504	7504	7504
10.2	76	1064	2432	4256	5016	5016

+	Jul	Aug	Sep	Oct	Nov	Dec
1.1	25204	25204	25204	25204	25204	25204
1.2	30781	30781	30781	30781	30781	30781
1.3	12996	12996	12996	12996	12996	12996
1.4	22010	22010	22010	22010	22010	22010
1.5	16005	16005	16005	16005	16005	16005
1.6	28253	28253	28253	28253	28253	28253
1.7	14277	14277	14277	14277	14277	14277
1.8	15643	14619	11244	0	4093	0
1.9	3774	3929	3015	0	1598	0
1.10	5042	4772	3799	0	4310	0
1.11	2500	2367	1884	0	2083	0
1.12	16009	14982	11525	0	4203	0
1.13	3797	3953	3033	0	1375	0
1.14	6201	5869	4673	0	4508	0
1.15	9895	9895	9895	9895	9895	9895
2.1	23270	23270	23270	23270	23270	23270
2.2	30583	30583	30583	30583	30583	30583
2.3	32597	32597	32597	32597	32597	32597
2.4	18490	18490	18490	18490	18490	18490
2.5	30617	30617	30617	30617	30617	30617
3.1	22150	22150	22150	22150	22150	22150
3.2	10199	10199	10199	10199	10199	10199
3.3	21150	21150	21150	21150	21150	21150
3.4	21467	21467	21467	21467	21467	21467
3.5	20279	20279	20279	20279	20279	20279
3.6	19411	19411	19411	19411	19411	19411
3.7	21112	21112	21112	21112	21112	21112
3.8	9180	9180	9180	9180	9180	9180
3.9	16765	15771	12747	0	2769	0
3.10	15605	15884	12650	0	2769	0
4.1	44084	44084	44084	44084	44084	44084
4.2	27474	27474	27474	27474	27474	27474
4.3	42747	42747	42747	42747	42747	42747
4.4	41125	41125	41125	41125	41125	41125

4.5	39360	39360	39360	39360	39360	39360
4.6	39672	39672	39672	39672	39672	39672
4.7	29022	29022	29022	29022	29022	29022
4.8	25660	25660	25660	25660	25660	25660
4.9	19270	18741	14361	0	5723	0
5.1	12753	12753	12753	12753	12753	12753
5.2	15351	15351	15351	15351	15351	15351
5.3	19316	19316	19316	19316	19316	19316
5.4	10976	10843	12450	0	1228	0
5.5	13903	12744	11105	0	2189	18
5.6	17512	19378	19074	1055	1699	867
5.7	10976	10843	12450	0	1228	0
5.8	13020	13870	16222	366	1138	2
5.9	16606	18378	18360	1069	1554	825
6.1	21056	21056	21056	21056	21056	21056
6.2	12163	12163	12163	12163	12163	12163
6.3	10470	10470	10470	10470	10470	10470
6.4	16047	16360	16461	0	1375	0
6.5	8064	7530	11588	0	1804	28
6.6	5232	4790	8098	219	1797	997
6.7	16047	16360	16461	0	1375	0
6.8	11652	12576	14008	609	2340	1356
7.1	25931	25931	25931	25931	25931	25931
7.2	24573	24573	24573	24573	24573	24573
7.3	17509	17509	17509	17509	17509	17509
7.4	23497	24511	24137	30	630	0
7.5	16125	16445	16523	0	2574	0
7.6	24879	25991	25318	14	715	0
7.7	14402	14572	15162	0	2782	738
8.1	6562	6562	6562	6562	6562	6562
8.2	5566	5566	5566	5566	5566	5566
8.3	3104	3754	2905	184	1248	207
9.1	9547	11544	8807	620	5455	924
10.1	7504	7504	7504	7504	7504	7504
10.2	3648	4256	3344	304	608	91

;

I.4.2. family labour availability (hour)

table famlabav(rr,fff,t) Family labour availability (hours per month)

$ontext

Family labour availability was chosen differently according to the local conditions. In Al-Hassakeh where almost all farms are managed directly by sharecroppers,

we assumed high number of family labour availability. These numbers are calculated by dividing the total farm size by 3, assuming that each 3 hectares requires one

full-time labourer, then the resulting number was multipied by 150 which is the number of hours per month. The justification is that sharecropping labour has

all the characteristics of family labour (I have to find theoritical support for this argument, or present a discussion that makes uses of theorems of sharecropping)

In Al-Rakka, where all farms are managed directly by the owners, we assumed that each family devotes 2 memebers full time and one part-time (50% of its time)

The only exception is Tal-Abiad, where farms are mostly managed by investors from outside the region, here we assumed only one family labourer full time.

In Deir-ez-Zor, where farms are also managed by owners, we assume that each family devotes two members full time only.

Although some may argue that in Al-Rakka and Der-ez-Zor, families may be able to devote more memebrs, we have observed from the survey that in general

other family memebrs are involed in other activities: e.g. livetstock (sheep), public employment, or working abroad, etc.

$offtext

	jan	feb	mar	apr	may	jun
1.1	828	828	828	828	828	828
1.2	873	873	873	873	873	873
1.3	338	338	338	338	338	338
1.4	434	434	434	434	434	434
1.5	270	270	270	270	270	270
1.6	847	847	847	847	847	847
1.7	414	414	414	414	414	414
1.8	912	912	912	912	912	912
1.9	286	286	286	286	286	286
1.10	487	487	487	487	487	487
1.11	228	228	228	228	228	228
1.12	940	940	940	940	940	940
1.13	257	257	257	257	257	257
1.14	465	465	465	465	465	465
1.15	256	256	256	256	256	256
2.1	695	695	695	695	695	695
2.2	654	654	654	654	654	654
2.3	1256	1256	1256	1256	1256	1256
2.4	693	693	693	693	693	693
2.5	655	655	655	655	655	655
3.1	673	673	673	673	673	673
3.2	202	202	202	202	202	202
3.3	672	672	672	672	672	672
3.4	695	695	695	695	695	695
3.5	699	699	699	699	699	699
3.6	648	648	648	648	648	648
3.7	671	671	671	671	671	671
3.8	195	195	195	195	195	195
3.9	720	720	720	720	720	720
3.10	734	734	734	734	734	734
4.1	1210	1210	1210	1210	1210	1210
4.2	636	636	636	636	636	636
4.3	681	681	681	681	681	681
4.4	1137	1137	1137	1137	1137	1137
4.5	1135	1135	1135	1135	1135	1135
4.6	1204	1204	1204	1204	1204	1204
4.7	940	940	940	940	940	940
4.8	1156	1156	1156	1156	1156	1156
4.9	1167	1167	1167	1167	1167	1167

5*6.1*9	375	375	375	375	375	375
7.1*7	150	150	150	150	150	150
8*10.1*3	300	300	300	300	300	300
+	jul	aug	sep	oct	nov	dec
1.1	828	828	828	828	828	828
1.2	873	873	873	873	873	873
1.3	338	338	338	338	338	338
1.4	434	434	434	434	434	434
1.5	270	270	270	270	270	270
1.6	847	847	847	847	847	847
1.7	414	414	414	414	414	414
1.8	912	912	912	912	912	912
1.9	286	286	286	286	286	286
1.10	487	487	487	487	487	487
1.11	228	228	228	228	228	228
1.12	940	940	940	940	940	940
1.13	257	257	257	257	257	257
1.14	465	465	465	465	465	465
1.15	256	256	256	256	256	256
2.1	695	695	695	695	695	695
2.2	654	654	654	654	654	654
2.3	1256	1256	1256	1256	1256	1256
2.4	693	693	693	693	693	693
2.5	655	655	655	655	655	655
3.1	673	673	673	673	673	673
3.2	202	202	202	202	202	202
3.3	672	672	672	672	672	672
3.4	695	695	695	695	695	695
3.5	699	699	699	699	699	699
3.6	648	648	648	648	648	648
3.7	671	671	671	671	671	671
3.8	195	195	195	195	195	195
3.9	720	720	720	720	720	720
3.10	734	734	734	734	734	734
4.1	1210	1210	1210	1210	1210	1210
4.2	636	636	636	636	636	636
4.3	681	681	681	681	681	681
4.4	1137	1137	1137	1137	1137	1137
4.5	1135	1135	1135	1135	1135	1135
4.6	1204	1204	1204	1204	1204	1204
4.7	940	940	940	940	940	940
4.8	1156	1156	1156	1156	1156	1156
4.9	1167	1167	1167	1167	1167	1167
5*6.1*9	375	375	375	375	375	375
7.1*7	150	150	150	150	150	150
8*10.1*3	300	300	300	300	300	300

;