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The Foreseen Impact of the Recent Policy Reforms and Other Scenarios on Water Use in Syrian Arab Republic:

the Case of Al-Khabour Basin

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Foreword

This paper aims to contribute to the continuous process of supporting the Syrian development and modernisation process by enriching public availability of documentation on agricultural economics and policy studies conducted at the National Agricultural Policy Center (NAPC).

The studies and research activities carried out at the NAPC involve the preparation of papers to consolidate the outcomes of on-going researches which provide a reference for future follow-up. The collection of such documents in the NAPC allows sharing with a wider public research results susceptible of further analysis and elaboration.

Syrian agriculture is characterised by a variety of geographically and socio-economically differentiated production systems. Available information on the structural articulation of these systems is scanty. In order to contribute in filling the perceived gap, the NAPC launched the process of conducting the first systematic supply and demand study for agricultural commodities in the country, with the support of the FAO Project GCP/SYR/006/ITA - Phase III, funded by the Italian Government.

The study lasted for about three years and was conducted by the workforce of the Agro-Food Systems Division and led by Mr Carlo Cafiero, FAO International Consultant, under the supervision of the Project CTA, Mr Pirro-Tomaso Perri, and the NAPC Director, Mr Atieh Al-Hindi. In the implementation of the study, the division was supported by the Project Agricultural Economist and the FAO consultant , Ms Ilaria Tedesco.

The study work started by a preparation period that lasted for a year aiming at collecting all relevant information for the study. This information has been all summarised and presented in their relevant commodity outlooks and bulletins, which have been consistently published by NAPC.

From the beginning, the study was divided into two major parts: the supply part that analyses the agricultural production at the farming system level and the demand part that considers the commodities passing down their chains reaching their final users.

This paper was produced benefiting from the data collected and the model constructed to analyse the agricultural production at the farming system level. Although the research activities of the production analysis are not finished yet, the authors made use of the analytical model to perform some policy simulations concerning a hot topic for Syrian agricultural policy: water deficit in the region of Al-Khabour basin. This paper summarises these simulations and draw some policy implications from them.

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Acronyms

ACB	Agricultural Cooperative Bank
AHG	Al-Hassakeh Governorate
GCASR	General Commission for Agricultural Scientific Research
GECPT	General Establishment for the Cereal Processing and Trade
CMs	Cubic meters
CMO	Cotton Marketing Organisation
GOS	Government of Syria
KTB	Al-Khabour and Tigris basin
MAAR	Ministry of Agriculture and Agrarian Reform
MI	Ministry of Irrigation
NAPC	National Agricultural Policy Centre

Introduction

Water irrigation sector has an important role in agricultural development especially in reducing the effects of rainfall variability, which is of a great relevance in arid and semi-arid environments, as mostly the case in Syria. Therefore, although in Syria, the irrigated areas account only for about 25% of cultivated areas, the agricultural output heavily depends on them, since irrigated areas produce 100% of summer crops and 45-70% of winter crops depending on rainfall variability across time. Consequently, the Government of Syria (GOS) put in place many interventions to increase the irrigated agricultural area, which indeed has increased steadily in Syria over the last decades, almost doubling since 1985 (NAPC 2005[a]).

However, Syrian water resources are quite limited as compared to the needs of the country. Recent estimates show that the overall water balance for Syria is negative with a deficit of more than three thousand millions m^3 per year (Varela-Ortega & Sagardoy 2001). In such a context, water for agriculture plays a crucial role. It accounts for 85% of the total use and, even more important, it is mainly used for water-intensive crops, especially cotton and wheat, which are currently the most important crops in Syrian agriculture. Both of them occupy a significant portion of the cultivated areas of Syria. Cotton occupies about 20% of the irrigated area, while wheat is cultivated in all parts of the country, as a rainfed or irrigated crop depending on the rainfall and available irrigation water. These two crops are considered strategic from the GOS's viewpoint as wheat is the main staple food item in the country, while cotton is the second main provider of foreign currency (after oil). In addition, they both provide the agri-industrial sector with the necessary raw materials (NAPC 2006).

However, since these two crops require much water to yield acceptable levels of output in the context of the Syrian agro-ecological conditions, they have significantly contributed to the water deficit problem in the country. Their negative effect on water is obviously observed in the area of Al-Khabour and Tigris basin (KTB), where cotton and wheat dominate the cropping patters in almost all irrigated farms (NAPC 2005[a]).

Given the above, this working paper aims at assessing the impact of the current policy on the agricultural use of water in Al-Hassakeh Governorate, and to assess the impact of possible change in the cropping patterns or/and the irrigation techniques pursued by the farmers of Al-Hassakeh that might result from any policy change, since the GOS, in an attempt to solve the water deficit problem, is encouraging farmers to modify the cropping pattern (by cultivating alternative crops that consume less water) and adopt water saving techniques (drip and sprinkler schemes).

This report starts with a discussion of the relevant policy issues, hinting to the background and justifications of the paper. Chapter 2 summarises the methodology and data used in the analysis, followed by two chapters summarising the results and conclusions. The paper is ended with an appendix.

Chapter 1 - Policy Issues

As this research aims at assessing the impact of the GOS policies on water use in Al-Hassakeh Governorate (AHG), it is important to provide a brief description of these policies and their rationales from the GOS's viewpoint, given that the GOS has been recently undertaking dramatic policy reforms that are expected to have substantial socio-economic effects spelling over all economic sectors, in terms of resource allocation and income distribution.

Cotton and wheat dominate the cropping patterns of AHG's irrigated farms. They occupy about 20% and 78% respectively. Barley is also grow in AHG's irrigated farms, however, its area does not exceed 2% of the total irrigated land (NAPC database, author elaboration).

Cotton is considered a strategic crop in Syria and it occupies about 20% of the irrigated land. Cotton area has fluctuated around 200 thousands hectares during the last decade with a total output of about one million tonnes. It occupies the first place among agro-industrial crops in terms of production value, ranks the second among exports (after petroleum), and is the third most important contributor to GDP after petroleum and wheat (NAPC 2006, P. i). Wheat, in turn, occupies about 70% of the irrigated land and more than 30% of rainfed cropping area. Its high importance is because it is the main source of food, given that Syrian diet depends very much on wheat products, mainly bread.

For these reasons, the GOS through the the Ministry of Agriculture and Agrarian Reform (MAAR) sets fixed producers' prices for these two crops. The pricing mechnism depends on production costs calculated by the MAAR departments allover the country after adding some profit margins.

The official price of wheat has been until recently equal to SP 11.8 per one kilogram, but it also differs according to some quality charactristics (this is for durum wheat, while the price of soft wheat is about one SP less). In reality, most farmers used to get a price that slightly fluctuated around SP 11.5 per one kilogram. Cotton price also differs according to quality, but it also differs according the delivery date of output, to motivate farmers for an early harvest for the sake of avoiding the bad impact of early rainfall on cotton fibre. The prices have been until recently as follows: SP 30.75 per kilogram for the period from the beginning of the harvest season until November 15th, SP 26.25 per kilogram from November 16th until November 30th, and SP 19.75 per kilogram from December 1st until the end of the season. However, more than 95% of the total output is delivered during the first period. As for wheat, these prices refer to the maximum price a farmer can get, while the average price in reality that farmers used to get has fluctuated around 27.5 SP/kg.

This pricing mechanism aims at motivating farmers to grow these important crops, assisting the GOS in achieving its strategic goals in stimulaitng industrial growth, achieving a certain level of food self-sufficiency (as a tool for food security), improving the balance of payments position through exports, obtaining foreign currency, etc. The governmental agencies responsible for cotton and wheat are the Cotton Marketing Organisation (CMO) and the General Establishment for Cereals Processing and Trade (GECPT).

Moreover, diesel is a very important input for Syrian irrigated farms who need to pump the irrigation water from its source in order to avail it onto the fields. In our case, such an input is greatly important for farms whose water source is either private wells or rivers, since public networks water is usually driven to fields by gravity (it does not require pumping). Most pump-sets in the region in question work on diesel, while the rest uses electricity. Deseil and electricity, in Syria, has been soon highly supported by the GOS. For example, the consumer price of diesel in the neighbouring countries (Lebanon e.g.) fluctuates from 25 to 35 SP/litre (in line with the world price fluctuations), while it has been fixed in Syria at 7.40 SP/litre. Electricity has a similar situation especially that many power generating stations in Syria still use diesel.

The recent price policy of diesel and electricity had two reasons. The first one was to support consumers as Syrian people depend mainly on diesel for heating in winter. The second aimed at supporting economic development, agricultural and industrial, through providing cheap source of energy. However, this policy has caused a drain on the budget after the increase in international prices that caused the smuggling of huge quantities of diesel from Syria (where prices are very low) to the neighbouring countries especially Lebanon (where prices are in line with the international ones), raising concerns about the sustaianbility of such policy that led the new reform.

Recently, the GOS has undertaken a series of policy reforms that are relevant to the question of this paper. Most important was the decision to raise the price of diesel to 25 SP/litre (an increase of 238%). However, and in attempt to reduce the potential negative effects on farms' profitability, the decision was followed by increasing the prices of the main strategic crops, coupled with direct payment support for cotton irrigated from private licensed wells (by decisions No. 27 and 31/2008 of the MAAR). Therefore, the prices of wheat, barley and cotton have become 20, 15, and 41 SP/kg, while the direct payment support of cotton irrigated by wells is 30,000 SP/hectare. Therefore, it is of interest to simulate such policy reforms to foresee their potential impacts on water use in the region in question.

Other relevant policy measures that started to draw the attention of policy makers in order to solve the problem of water deficit in Syria are the promotion of modern irrigation schemes and the development of alternative crops that require much less irrigation water than do wheat and cotton. In this context, the GOS has recently established a new department in the MAAR to supervise the trasnfer of irrigated farms from the flood irrigation scheme to the modern techniques (drip and sprinkler), given that the total area irrigated by modern techniques does not exceed 15% of the total irrigated area in the country. Therefore, it is interesting to assess the impact of this transfer on water use in the region in question.

In the same context, the MAAR in collaboration with the Ministry of Irrigation (MOI) and the Italian Cooperation, has established a project to promote some rainfed crops grown in the same region in the rainfed farms. These crops are considered promising in the international markets due to their recent increasing demand, given that these crops require cheap storage conditions, which facilitate their management by governmental agencies without experiencing significant quality deterioration. These crops are lentil and chickpea, for which the GOS sets now a floor price that were until recently equal to SP 16 and and SP 17.8 per kilogram respectively (their prices have been recently increased to 23 and 25 SP/kg for lentil and chickpea respectively) besides to the high costs of harvesting (manual), making them unattractive by farmers who have access to irrigation water given the high gross margins generated by growing cotton and wheat. Cumin is also considered by the project for the same reasons although it is a new crop in AHG, but it has the similar characteristics to those of lentil and chickpea concerning storage conditions and water requirements. In addition, its price has recently been very high (about 120 SP/kg in 2006) reflecting its increasing demand. It is, therefore, interesting to assess the impact of introducing these crops to the AHG's irrigated farms on water use, which might result from any change in their pricing policy.

Chapter 2 - Methodology

The analytical tool used in this research is the modelling of representative farms through mathematical linear programming. Applying this method reuiqres the classification of AHG irrigated farms into a relatively small number of representative farm types. This classification should take the following criteria into consideration:

1. the boudaries that separate different administative districts. This is useful because data collection by governemtal agencies is mainly based on these boundaries.

2. the boundaries that separate agro-ecological zones. This is important because, as in the previous case, many data collected by governmental agencies are based on these boundaries. In addition, different agro-ecological zones have important effects on water requirements (i.e. water use) of the cultivated crops in different areas since these zones are determined according to the average level of rainfalls.

3. irrigation water sources, which are three in AHG: private wells, public nets, and rivers. Water source usually affects water cost, which, in turn, affects the decision making of farmers.

4. the farm size, which has an impact on the economy of scale, affecting the profitability of the farm as well as its ability to the adoption of new technologies.

5. cropping patterns, since different farms might grow different crops reflecitng specialisation. This affects water use since different crops have different water requirements.

6. irrigation techniques: flood, drip, or sprinkler. They clearly have an impact on water use, as modern techniques save water in comparison with the flood traditional technique. Therefore, modern irrigation schemes affect the composition of production costs which influence the decision making of the farmer.

2.1 A general model for policy evaluation

The production function of a farm can be given by:

$$h(\underline{q}, \underline{x}, \underline{z}) = 0 \qquad (1)$$

where $\underline{q}$ is the vector of output quantities, $\underline{x}$ is the vector of variable input quantities, and $\underline{z}$ is the vector of fixed factor quantities. Variable inputs are usually hired labour, fertilisers and other chemicals, seeds, hired machinery, and all other inputs that can be purchased in desired quantities. Fixed factors are private factors that cannot be acquired in the time span analysed such as land and equipment, and public factors such as roads and extension services and other exogenous features such as weather and distances from markets.

Assuming that p and w are the prices of outputs and inputs respectively, the producer's gross margin is given by $p'q - w'x$. Assuming a profit-maximisation behaviour of the producer subject to technology constraint:

$$Max \ \ pq - wx \qquad s.t \ \ h(\underline{q}, \underline{x}, \underline{z}) = 0 \qquad (2)$$

The solution to this problem provides a set of output's supply and input's demand functions at the individual farm level, which heavily depend on the technology described in the production function (1).

Representing the farm profit-maximising problem (2) through *mathematical programming* requires some simplifying assumptions:

1. the use of variable inputs can be described by their per-unit cost, so that the objective function described in equation (2) simplifies to

$$Max \sum_{i=1} \tilde{p}_i q_i \tag{3}$$

where:

$\tilde{p}_i = (p_i - c_i)$

where:

c_i is the per-unit cost of variable inputs for *i*-th crop.

p_i is the per-unit price of the output for *i*-th crop,

2. the technology is described by

$$Aq \leq z \tag{4}$$

where:

A is a matrix of technical coefficients expressing the unit requirements of fixed resources.

The elements of this matrix, a_{ji}, indicate the amount of the *j*-th fixed factor required to produce one unit of *i*-th output. Typical relevant fixed resources include land, family labour, liquidity (cash availability), and water.

Additional rows to the matrix *A* can be included to describe the relevant technological constraints, such as cropping rotation requirements, as well as relevant policy constraints such as crops' licensing systems.

Therefore, in order to estimate the derived demand for water, we need a model that represents the aggregate behaviour of the irrigated farms' sector in AHG. The model used in this study is based on a bottom-top approach. It starts with modelling the behaviour of individual farming systems that allows estimating the derived demand for water of each individual farm type. By aggregating the demand for water of all the farm types, we obtain the aggregate demand for water of AHG's farming sector to be used in assessing the incidence of possible alternative policies on agricultural water use in Al-Hassakeh governorate.

To put this model into application, it is required to make an assumption on the technology at the individual farming system level. The simplest assumption is to assume fixed coefficients, which implies constant marginal costs. This assumption requires that the production costs and total outputs of various crops be given per area unit (per hectare e.g.).

Given this assumption, the model formulae given by equations (3) and (4) are manipulated as follows:

$$Max\ GM = \sum_i (p_i y_i - c_i) h_i \quad \text{for } i = 1,2,\ldots\ldots,m \tag{5}$$

Subject to:

$$\sum_i h_i \leq H \qquad \text{total area less or equal to the farm size} \tag{6}$$

$\sum_i a_{ij} h_i \leq b_j$ total availability of other fixed resources (7)

$f(h_1, h_2, \ldots, h_n) \leq 0$ rotation requirements and policy constraints (8)

where:

GM is the total gross margin of the farmer (GM = total revenue – variable costs);

H is the total farm size;

p_i is the price of the product of the *i*-th crop;

y_i is the yield of the *i*-th crop;

c_i is the per area unit variable costs of the *i*-th crop;

h_i is the area cultivated with the *i*-th crop;

b_j is the availability of the *j*-th resource (such as water);

$a_{i,j}$ is the requirement of the *j*-th resource for one unit of land cultivated with the *i*-th crop;

$f(.)$ is the function that defines a set of constraints on the relative dimension of the various crop areas to obey agronomic rotations among crops or to obey policy constraints such as cotton licensing system (see below).

While the assumption of fixed coefficients is made for simplicity, the model described above ignores all problems associated with risk and uncertainty, in the sense that it implies the assumption that farmers are risk-neutral which is the exception rather than the rule. Although risk is embedded in every economic activity, agriculture and its related industries are characterised by an unusually high degree of risk. This is due especially to the reliance of agriculture on biological processes and its susceptibility to the vagaries of climate and weather. Added to this is the inelasticity in the supply and demand for agricultural commodities, which can lead to large price fluctuations in agricultural markets when harvests are exceptionally bad or good.

This leads us to the conclusion that farmers in reality do not really maximise profits, they rather attempt to do so, given the available information, technology and states of nature, while facing various sources of risk that 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 causes fluctuations in prices, and in both cases, the total net revenue experiences high degree of uncertainty.

However, the assumption of profit maximisation in the context of this study is not without empirical justifications. Given that the most serious effect of exposure to weather is due to rainfall fluctuations, such effects are minimal in our case because the farms considered are all wholly irrigated. 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 reducing or eliminating the risk of underutilisation from the side of plants of some other inputs such as chemical fertilisers. Furthermore, risks associated with markets and reflected in form of price fluctuations are minimised by the agricultural pricing policy of the products that prevail the cropping patterns in the region in question. All crops grown in AHG either have fixed price (cotton) or have floor price (wheat and barley).

Therefore, profit maximisation model described above, though it has the advantage of simplicity, will not however enable us to perform any simulation that incorporates risk, meaning that we can only perform simulations by changing some policy parameters (mainly prices), but we will not be able to predict what would happen if the entire policy were dropped.

2.2 Definition of constrains

Constraining resources

With reference to the preceding section, fixed resources are land, water, family labour, and all other private factors that cannot be acquired in the time span analysed such as cash availability in addition to the public factors such as roads and extension services and other exogenous features such as weather. Since our research is confined to one limited geographical area, we can assume that the impacts of roads, extension services and weather are approximately the same on all farms. This assumption is supported by some general observations made through the survey. Therefore, we only focus on land, family labour, water and cash availability. 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 traditional contractors, the C*haweshes*, who pool agricultural labour in areas where there is excess supply 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.

Concerning cash, it is reasonable to say that irrigated farms of AHG do not face cash constraint principally due to the short-term agricultural credit system managed by the Agricultural Cooperative Bank (ACB) that favours the so-called strategic crops (wheat, cotton, sugarbeet, barley, chickpea, lentil, and tobacco). Farmers who produce any of these strategic crops have access to short-term loans that cover the costs of seeds and fertilisers provided in kind, while some in cash loans are also provided to cover some other operations such as weeding and chemical applications. It is noticeable that the three crops that are mostly relevant in AHG are among these crops (wheat, cotton, and barley). The other variable costs that are not supported by the credit system such as rental machinery and hired labour costs are easily managed by the 'informal credit market', in the sense that the payment of a substantial proportion of these costs, if needed, can be postponed until the output is sold.

Therefore, as far as farmers produce these three crops, they do not face any cash constraint. However, it might be probable that that such credit system constrains the cultivation of some crops (such as cumin). This is investigated in the simulations of the model. For now, we will assume that farmers do not face any cash constraint.

However, the possibility that water is a constraining resource in the Syrian agriculture seems to be quite high. This has been approved by previous research, stating that most water basins in Syria suffers from water deficit mainly due to the intensive use of water in agriculture that uses about 80% of the total water use of the country (Ortega & Sagardoy, 2001) (NAPC, 2005).

Policy-imposed constraint

Another constraint that Syrian farmers face is imposed by the policy of agricultural licensing system regarding the production of cotton. This system imposes a limit to the maximum area of cotton that a farmer can cultivate in order to receive the official price for all of his/her output, which is said to be much higher than the prevailing world price. If a farmer produces cotton in excess of his/her license, he/she would receive a price that is much lower than the official one and more in line with the price prevailing at the world market. However, the survey results of the research proves that it is not easy for farmers who might be willing to produce cotton in excess of their license to do that due to the difficulties they face in purchasing cotton seeds that are well controlled by the ACB.

Other constraints

Barley and wheat crops are very similar in terms of technical requirements, cost structure, and some aspects of policy intervention. The only difference exists in their pricing policy. Although both crops have floor prices (while cotton has a fixed price) wheat price (SP 11.5/kg) is much higher than that of barley (SP 7.5/KG) in 2007. Given the above information, our linear programming model would always select only the crop that has a higher price (wheat), while barley would be totally absent from the cropping patterns.

The secondary data sources suggest that only some farms produce barley in limited quantities. This has been proved by the survey findings, which has also proved that these farms do not grow barley for sale (whether to the GOS or in the marketplace). They rather grow barley for the sake of feeding their livestock (mainly sheep).

The best way of considering this fact in our linear 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 constraints, and to the fact that including sheep flocks in the analysis would not significantly improve our model concerning the measurement of the agricultural policy impact on water use. This is because sheep herds consume negligible amounts of water in comparison to those of crops such as wheat, cotton, and barley, given that the herds spend at least half of the year away from the farms, grazing the pastures in the Syrian steppe (Al-Badia).

Therefore, the solution proposed here to deal with this problem is reached by assuming that each farm has to produce a minimum amount of barley for the sake of feeding the livestock. This amount is measured in terms of land area occupied by barley given that yield is fixed (which is a reasonable assumption for irrigated farms in the short-run). Then the area occupied by barley is exactly equal to the observed one, which is translated in our model by setting a constraint saying that the area planted with barley must be equal to or greater than the observed area of barley.

Another constraint is imposed by the agrarian rotations that AHG's irrigated farms pursue. According to the survey findings, farmers follow a very simple rotation advised by the technical experts of the local agricultural departments. They divide the crops into cereals (wheat and barley) and non-cereals, which are cotton, lentil, chickpea, and cumin although the last three crops are not observed in AHG's irrigated farms. The scientific basis of the rotation states that it is not advisable to grow any of the non-cereal crops 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.

2.3 Methodological note

To set up the applied model that takes into account all the constraints discussed above, we need to make a choice about the selected crops to be included in the model. It is stated above that the irrigated farms in AHG grow wheat, cotton and barley. However, this research is intended to assess the impact of policy change on water use. One interesting policy change might result in a change in the currently prevailing cropping patterns. This can be expressed as a change in the relative proportions of the present crops, but might also include new crops in the simulated solutions, requiring the inclusion of these crops in the model.

The most important candidates to be included in the model are cumin, lentil and chickpea. This is because these crops occupy now minor proportions of the rainfed farms, meaning that they are adapted to the agro-ecological conditions of the region and can be considered promising alternative crops for water-saving objectives if the policy changes to favour them. This is because they are all able to yield reasonably without irrigation in the context of the agro-climatic conditions of some parts of AHG, namely agro-climatic zones 1, 2, and 3 where the average rainfall is reasonably high. Therefore, the model includes six crops: wheat, cotton, and barley, in addition to cumin, lentil, and chickpea.

For the three crops that are not grown in AHG's irrigated farms (lentil, cumin and chickpea), but included in the model for simulations, their prices are assumed to be low enough to result a solution including their output equal to zero. Lentil and chickpea have a similar price policy to that of barley in the sense that the GOS sets floor prices for them. These floor prices are used (SP 16 for lentil and SP 17.8 for chickpea) despite the fact that their market prices have recently been higher than the floor price (almost SP 25 for lentil and SP 30 for chickpea). For cumin whose price is left to be determined through the market forces, its price is assumed equal to zero although its market price averaged about SP 120 in 2005 (NAPC database).

It must be noted, however, that setting the prices of these three crops very low compared to their market equivalents is just a matter of simplification of all constraints that prevent their cultivation in Al-Hassakeh irrigated farms. Some of these constraints have investigated during the survey. The market demand for these crops plays a crucial role in this respect as it is characterised by instability and ambiguity compared to that of wheat, cotton, and barley. Most farmers reported that they do not grow cumin because it is risky in terms of price and yield. The price risk results from the fact that there is no price stabilisation policy concerning cumin, while the yield risk is due to the sensitivity of its available varieties to the climatic and agronomic conditions (pests, diseases, rainfall, etc) in the absence of policy actions to reduce this sensitivity. The latter risk applies strongly also to chickpea and lentil. Although lentil and chickpea have floor prices making their markets relatively stable, farmers also reported that their current floor prices are too low to allow them to compete with the present crops.

Another issue to be discussed is the choice of irrigation techniques. The observed irrigation schemes in AHG's irrigated farms are flood, sprinkler, and drip. These three techniques are presented in the model using dummy variables that take values of zero or one. These dummies represent an 'investment switch' so they allow making simulations of switching farms from the flood scheme to 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 to the rainfed mode.

2.4 The model setting-up and validation

The data used in the farms' classification are available in the database of the National Agricultural Policy Centre (NAPC) and the Statistical Abstract of the MAAR (2005). The classification is performed through a process of disaggreagtion as follows:

- The entire irrigated area of AHG is divided according the district boundaries.
- The irrgated area in each district is divided according to the agro-ecological zones.
- The irrgated area in each agro-ecological zones is divided according to water sources.
- The irrgated area from each water source is divided according to irrigation techniques.

Therefore, farm types are distinct according to their location (district), agro-ecological zone, irrigation source, and irrigation technique. It is noticeable that differences in farm size and cropping patterns have not been taken in account in the classification process. We assume that this is not a problem as far as cropping pattern is considered, as AHG's irrigated farms have all simple quasi-homogeneous cropping pattern composed simply of wheat and cotton, in addition to small proportions of area under barley, but only in few farming systems. Differences in farms'size, on the other hand, have not been considered due to lack of data and information at the level of individual farming systems.

Nevertheless, the fieldwork of the research proves that differences in technologies among farms are negligible. Mechanisation level is almost the same for all farms regardless of the farm size. The same applies to the varieties of seeds and fertilisers used in plantation, for which the source is the same for all farms and all crops, which is the ACB. The only point that may raise some concerns is the level of family labour used on the farm that is expected to be different according to farms' size in which small farms tend to rely more on family labour in comparison with larger ones. Here the problem is solved relying on assumptions based on the findings of the fieldwork. Based on the above, we could assume that farm size does not affect the technology level and so is not that important for farms' classification.

The detailed description of data used in the analysis and the validation process is available in another volume and there is no need to repeat it here (**Sadiddin & Atiya, 2008, section 4.2**).

Chapter 3 - Foreseen Impact of Policy Change

The selection of simulations

The selection of possible simulations is mainly based on policy actions recently undertaken by the GOS and explained in **Chapter 1**. Although some of these policy alternatives were initially designed for the objectives of macroeconomic stability, they would likely have substantial impact on water problem at the national level as well as at the level of Al-Hassakeh governorate.

As explained in **Chapter 2**, the analytical model was validated and calibrated using the policy parameters of the reference year (2005). Therefore, the first simulation is based on adjusting the policy parameters to be in line with the recent policy reforms with the aim of predicting the changes in water use and balance and comparing them to their situations before the policy reform, hinting to the underlying changes in the cropping patterns. The second simulation aims to predict the potential impact of conevrting all farms to modern irrigation techniques, while the third aims at predicting the impact of increasing the prices of some potentially alternative crops.

3.1 The foreseen impact of the recent policy reforms

The simulation is performed by changing the policy parameters that were the target of the policy change. These are the prices of wheat, barley, and cotton, in addition to the decoupled payment directed to cotton production on private wells (refer to **Chapter 1**). Concerning the change in the price of diesel, the model does not allow simulating it directly since the costs of diesel is included in the cost of water. However, diesel cost by itself accounts for about 95% of the total pumping costs (Sadiddin & Atiya 2009, section 2.4). Thefore, we could conclude that the 292% increase in diesel price would lead to increase in the pumping costs by a lower percentage. In the simulation we assume an increase of 200%.

Table 3.1 summrizes the results of this simulation, demonstrating that the policy reform is expected to reduce water use and deficit by about 405 millions CMs. However, these reforms would not be able to restore the deficit totally as there would still be a deficit of about 509.24 million CMs.

Table 3.1 –the foreseeable impact of the recent policy reforms on water use and balance (millions CMs)

	[1]Water availability	Water use	Water balance
Before reforms	2388.00	3302.24	-914.24
After reforms	2388.00	2793.30	-405
The difference		-509.24	

Source: the results of the research

These changes in water use and balance are induced by changes in the cropping activities as shown in **Table 3.2**. The latter shows a switch from irrigated wheat from one side to rainfed

[1] water availability is estimated based on the maximum capacity of the pump-sets

wheat and irrigated barley on the other side, while all other cropping areas are unchanged. It is noticeable that none of the proposed alternative rainfed crops would enter the cropping patterns (refer to **section 2.3**), despite the increase in the production costs of the irrigated ones due to the increased pumping costs. This is because the increase in the prices of wheat, cotton and barley has partially offset the increase in water costs, but also because irrigated barley and rainfed wheat in some agro-climatic zones are still more profitable than the proposed alternative crops.

Table 3.2 – foreseeable impact of the policy reforms on cropping patterns (ha)

	Before reform	After reform	difference
Rainfed wheat	0	4035	4035
Irrigated wheat	340051	146926	-193125
Rainfed barley	0	0	0
Irrigated barley	14798	203888	189089
Irrigated cotton	82569	82569	0
Rainfed lentil	0	0	0
Rainfed chickpea	0	0	0
Rainfed cumin	0	0	0

Source: the results of the research

3.2 The foreseen impact of modernising irrigation schemes

This scenario intends to assess the impact of switching all the irrigated farms of AHG to modern irrigation techniques, whether sprinkler, drip, or both, after adjusting policy parameters to take into account the recent policy reforms. It is mentioned above that the initial solution of the model results in a total water use of 3303 millions CMs, before the reform, while the simulated solution after adjusting for the policy parameters results in 2793.3 millions CMs. Given that the current annual water availability in Al-Hassakeh is about 2388 millions CMs, there is a deficit of about 915 and 405 millions CMs respectively.

This simlation is composed of three scenarios. The first is to allow all farms to adopt sprinkler schemes only. The second permits all farms to switch to drip technique only, while the third allows all farms to have both techniques. The rationale behind the last scenario is that modern irrigation schemes are crop-specific, whereas sprinkler is suited for crops such as wheat and barley and drip is only suited for cotton, although the latter might be irrigated by sprinker scheme too. Therefore, farms that already have a sprinkler irrigation technique use it to irrigate all crops, but farms with only drip schemes use it only for cotton. In addition, there are some farms who have both techniques, in which they use the sprinkler method for wheat and barley but the drip for cotton.

Table 3.3 impact of adopting modern irrigation on water use and balance (millions CM)

The scenario name	Water use	Water availability	Water balance
The initial situation before reform	3303.24	2388	-915.24
The initial situation after reform	2793.3	2388	-405.3
All to sprinkler only	2587.2	2388	-199.2
All to drip only	2562.38	2388	-174.38
All to both	2422.86	2388	-34.86

Source: the results of the research

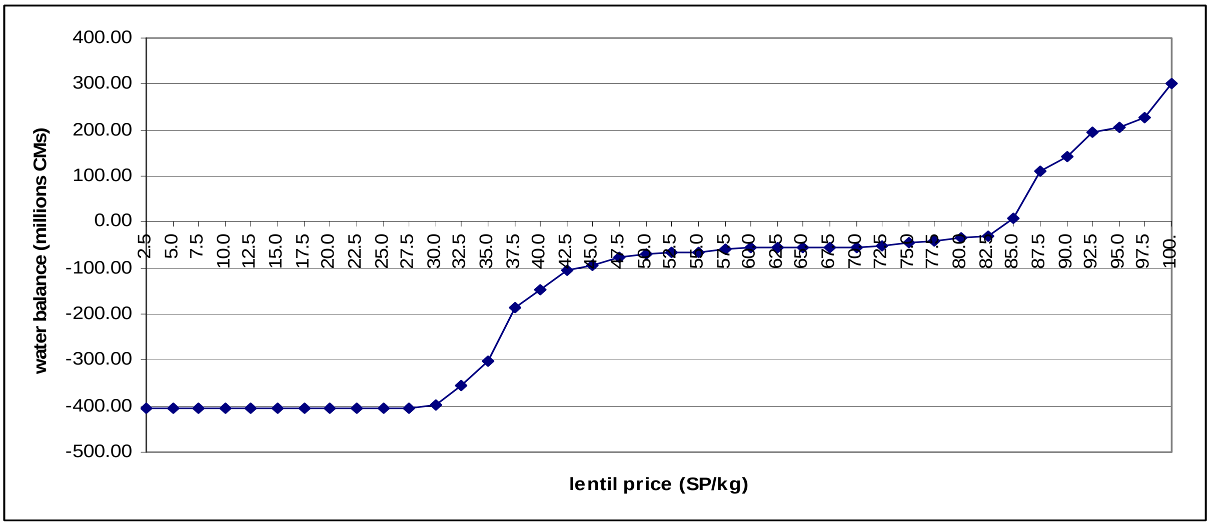
Table 3.3 summurises the results of the three scenarios. It shows that the switch to drip method saves water more than that of sprinkler method does, despite the crop-specific characteristic of drip method that makes it inappropriate for irrigating wheat and barley, meaning that the switch to drip technique allows only cotton to be irrigated by drip, while wheat and barley would continue to be irrigated according to the initial situation which is mostly flood. However, the largest amount of water saving occurs when all farms switch to both modern methods.

Nevertheless, even when all farms have the two modern irrigation schemes, there would still be a deficit of about 35 millions CMs.

3.3 The impact of changing lentil and chickpea prices

This simulation aims at assessing the impact of changing the prices of lentil and chickpea separately on water use and balance, after adjusting the policy parameters to be in line with the recent policy change. **Figure 3.1**, which shows the impact of lentil price change, suggests that water deficit remains constant at about 400 millions CMs until the price level of 25 SP/kg. Then it starts to go down rapidly until the price level of 50 SP/kg (which is very close to the recent market price), when it starts to go down slowly until reaching the price level of 85 SP/kg, where water deficit becomes zero.

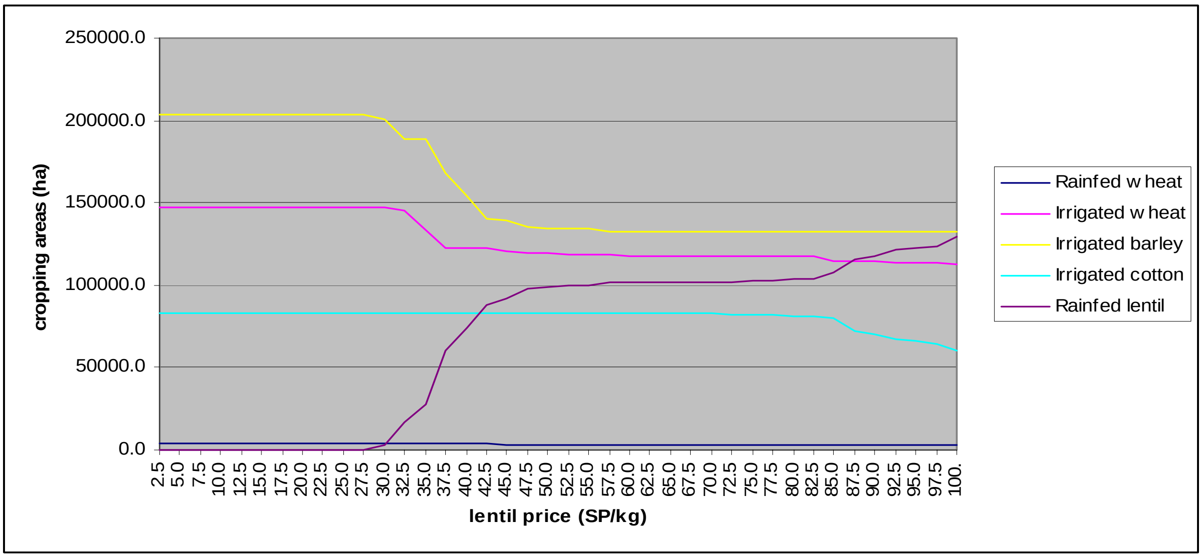
Figure 3.1 - impact of lentil price change on water balance



source: the research results

Figure 3.2 explains the change in water balance in terms of changes in the cropping patterns. It is noticeable that cropping patterns remain unchanged until the price of 25 SP/kg. The phase of dramatic decrease in water deficit is attributed according to **Figure 3.2** to the sharp decrease in the areas of irrigated wheat and barley which are replaced with rainfed lentil. The **Figure** also demonstrates that when lentil price goes up to more than 80 SP/kg, rainfed lentil starts to replace irrigated cotton. However, only cotton irrigated with flood and sprinkler techniques is replaced with lentil while cotton irrigated with drip scheme remains with constant cropping area (**Table 2** in **Appendix**)

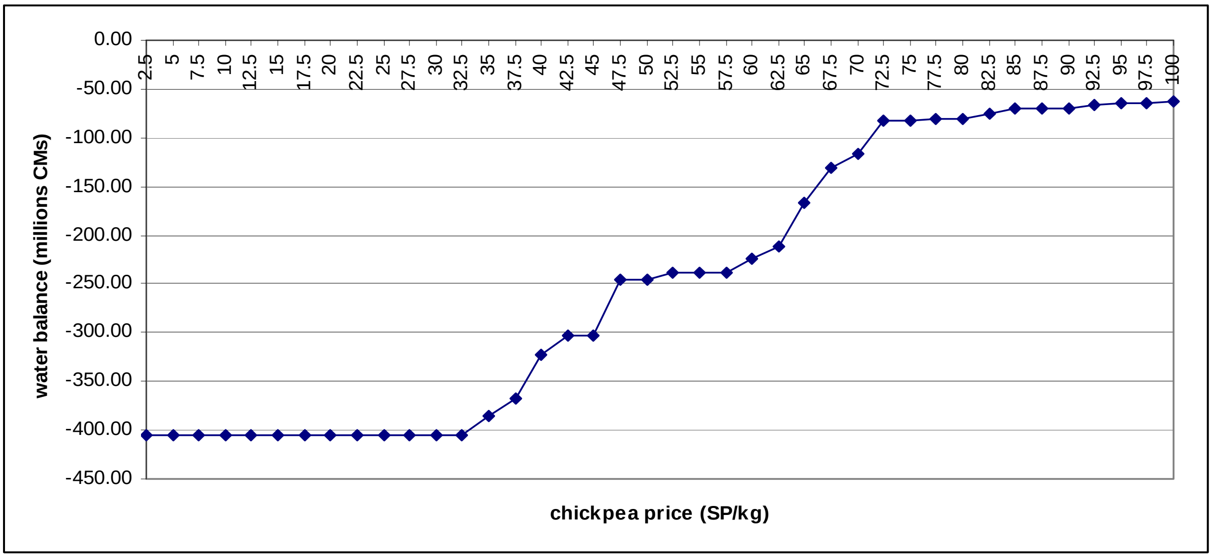
Figure 3.2 - Impact of lentil price change on cropping patterns



source: the research results

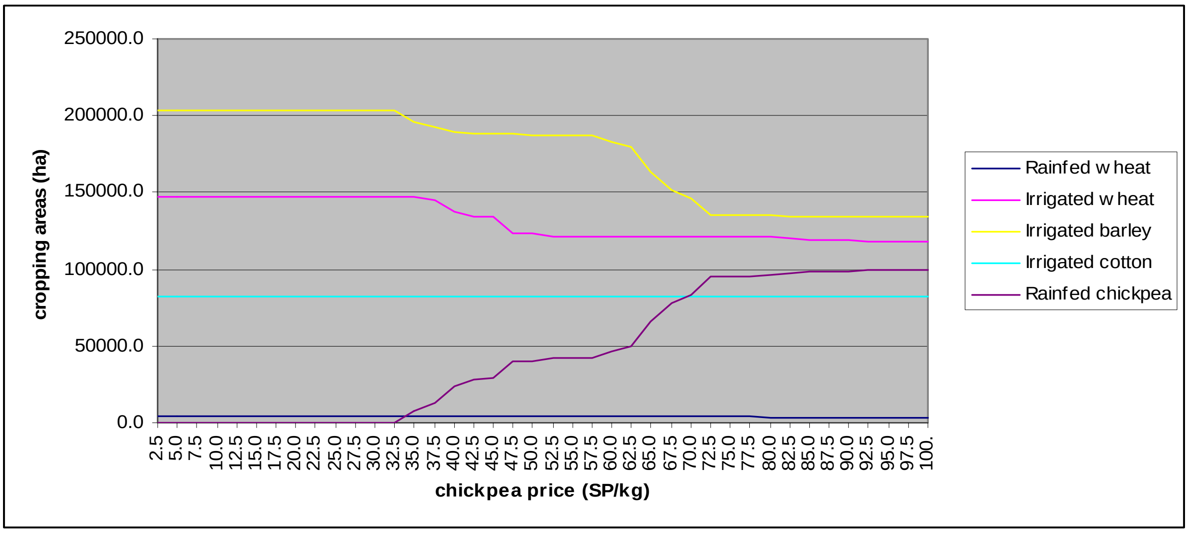
Figure 3.3, which demonstrates the impact of changing the price of chickpea, shows that water deficit remains constant at about 400 millions CMs until the price level of 30 SP/kg. Then it starts to go down rapidly until the price level of 70 SP/kg, when it starts to go down slowly. However, even when the price reaches the level of 100 SP/kg, there would still be a deficit of more than 50 millions CMs.

Figure 3.3 - impact of chickpea price change on water balance



source: the research results

Figure 3.4 - impact of chickpea price change on cropping patterns



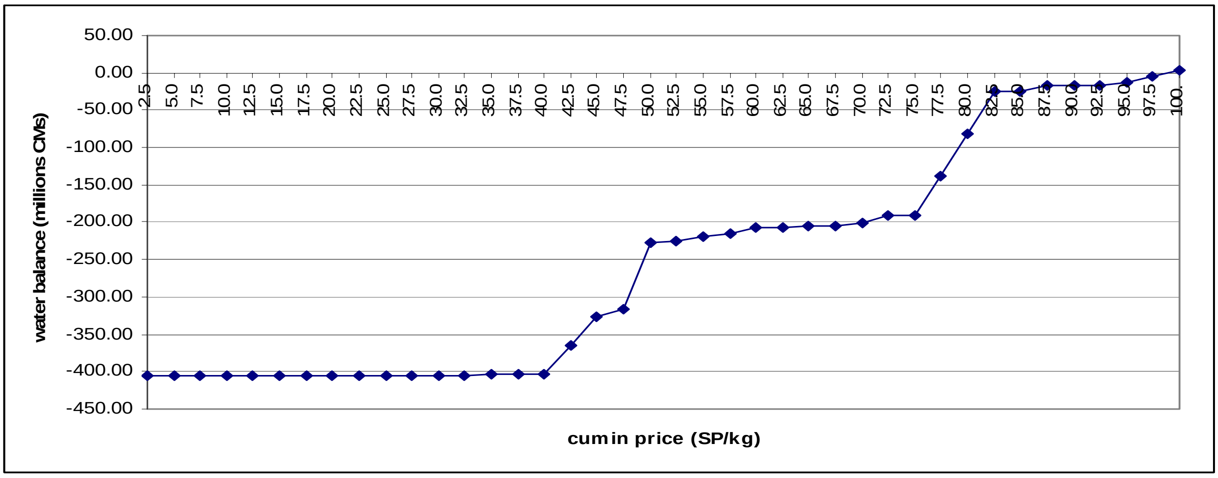
source: the research results

Figure 3.4 explains the change in water balance in terms of changes in the cropping patterns that correspond to changes in chickpea price. It is noticeable that cropping patterns remain unchanged until the price of 30 SP/kg. The phase of dramatic decrease in water deficit is attributed according to **Figure 3.4** to the sharp decrease in the areas of irrigated wheat and barley which are replaced with rainfed chickpea. However, **Figure 3.4** demonstrates cotton cropping area remains constant even when chicpea price goes up to more than 100 SP/kg.

3.4 The impact of introducing cumin into the cropping pattern

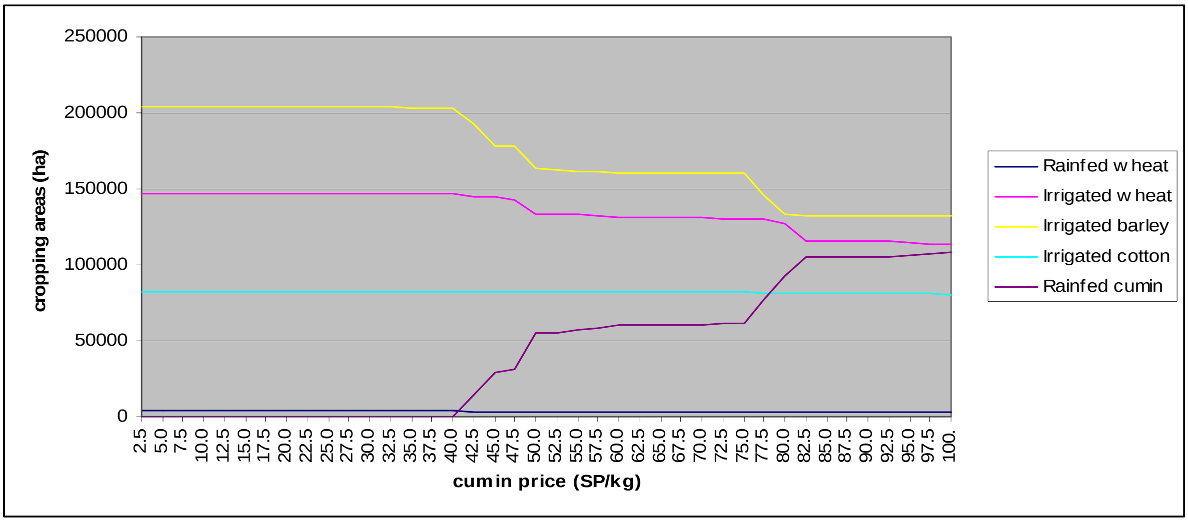
This scenario aims to evaluate the impact of introducing cumin into the cropping pattern. It is mentioned in **Chapter 2** that, in the initial situation, cumin price is set equal to zero to simplify all the constraints that prevent cumin cultivation by AHG's irrigated farms although its price recently has been very high. Therefore, the introduction of cumin into the cropping patterns is performed by raising its price, assuming that all constraints discussed in **Chapter 2** are erased by a policy action. As before too, the simulation is performed after adjusting all policy parameters to be in line with the recent reforms.

Figure 3.5- impact of cumin price change on water balance



source: the research results

Figure 3.6 - impact of cumin price change on cropping pattern



source: the research results

Figure 3.5 describes the impact of changing cumin price on water balance. It suggests that while water deficit remains unchanged until cumin price reaches the level of 40 SP/kg, it starts to decrease sharply between the prices 40 and 50 SP/kg. Then the decrease slows down between the prices 50 and 75 SP/kg, where it starts decreasing sharply again until reaching the price 82 SP/kg. However, only prices very close to 100 SP/kg could restore the deficit and produce a surplus.

Figure 3.6 explains the change in water balance in terms of changes in the cropping patterns that correspond to changes in cumin price. It is noticeable that cropping patterns remain unchanged until the price of 40 SP/kg. Then the first and second phases of dramatic decrease in water deficit is attributed according to **Figure 3.6** to the sharp decreases in the areas of irrigated wheat and barley which are replaced with rainfed cumin. Therefore, the decrease in water deficit is due to the switch of land under irrigated wheat and barley to cumin produciton. But at price 70 SP/kg, land under cotton also starts to switch to cumin production, although it is of importance to note that cotton area change is very slight.

Chapter 4 – Conclusions and Policy Implications

The results shown in **Chapter 3** demonstrate several conclusions. The recent policy reforms are expected to have a remarkable impact on water use and deficit, reducing the former by about 15% and the later by more than 50%. This change, however, is mainly due to the replacement of irrigated wheat with irrigated barley and rainfed wheat.

In addition, converting to modern irrigation schemes would further reduce water use and deficit, to an extent that depends on the modern technique used in the simulation. As expected, the best results occur when all farms would have both modern techniques so they can use sprinkler to irrigate wheat and barley, whereas drip can be used to irrigate cotton. In this case, water deficit goes down sharply to the level of about 35 Millions CMs.

However, this simulation assumes that farmers have no choice to expand the irrigated areas of their farms, which is not a necessarily true assumption. Many farmers irrigate only part of their farms because they do not have sufficient water for the rest. Therefore, water saved by using modern irrigation techniques might be used to expand the irrigated area, and so the net saving may become very low or even zero.

Furthermore, raising the prices of chickpea to a level higher than the one currently prevailing in the market has some impact on water use reducing the deficit to about 250 millions CMs instead of about 400 millions CMs. A similar comment can be made on the impact of raising the price of lentil, although the impact on water deficit is more significant (reduction up to less than 100 millions CMs). Introducing cumin price restores the water deficit when it approaches 100 SP/kg.

The rationale behind performing the last three scenarios is not based on the assumption that any of them alone can be considered a separate policy option. It is rather to demonstrate some results, which together, can provide insights for the formulation of a realistic policy option. The three crops have shown usefulness in solving the water deficit problem since they consume no water, and the only suggestion would be that the GOS would raise their prices to make them more attractive to the farmers. However, due to the high risk of rainfed agriculture due to its exposure to rainfall variability, farmers may disregard them from their options unless they can use supplementary irrigation to minimize the risk of natural hazard, which should be strongly accounted in any policy option.

Therefore, reforming the price policy of these crops should be coupled with other mechanisms to encourage farmers to cultivate them instead of cotton and not instead of wheat, since the former is much more water-intensive crop than the latter. This confirmation is justified by the fact that the model predicts that, as a consequence of increasing the price of any alternative crop, the relevant crop would replace wheat and not cotton due to the relatively higher profitability of the latter. Replacing cotton (but not wheat) has another important aspect related to the food security policy of the GOS, especially since wheat prices have recently increased dramatically at the international markets.

Moreover, introducing cumin through setting a fixed (or a floor) price is one that should be considered due to the following reasons. First, its current price is much higher than the one that restores water deficit according the study results. Second, it has very easy storage requirements which facilitate the involvement of parastatal agencies in its trade activities in a similar way to those of wheat and cotton. Third, it seems that cumin has a growing market internationally as indicated in other studies (NAPC 2005[b]). This might partially offset the negative effects of reducing cotton exports as a source of foreign currency.

These conclusions imply the presence of trade-offs between the objectives of the agricultural policy. The objective of saving water competes with food security objective and foreign currency requirements. However, some combinations of policy measures discussed above are possible to deal with water problem in the short-run. Of course, this does not underestimate the importance of other measures especially those related to conversion to modern irrigation method. But it must be noted that policy actions should not just focus on the conversion process, meaning that some emphasis should be made on providing farmers with the proper technical advice on how to use these schemes in ways that increase irrigation efficiency. Therefore, water saving can increase in combination with decreased water costs, making modern techniques more attractive to farmers.

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Appendix - Results of the Model Simulations

Table 1 - impact of lentil price change on water use and balance (millions CMs)

lentil price (SP/kg)	water use	water availability	water balance
2.5	2793	2388	-405
5.0	2793	2388	-405
7.5	2793	2388	-405
10.0	2793	2388	-405
12.5	2793	2388	-405
15.0	2793	2388	-405
17.5	2793	2388	-405
20.0	2793	2388	-405
22.5	2793	2388	-405
25.0	2793	2388	-405
27.5	2793	2388	-405
30.0	2785	2388	-397
32.5	2745	2388	-357
35.0	2691	2388	-303
37.5	2574	2388	-186
40.0	2534	2388	-146
42.5	2493	2388	-105
45.0	2481	2388	-93
47.5	2463	2388	-75
50.0	2457	2388	-69
52.5	2453	2388	-65
55.0	2453	2388	-65
57.5	2445	2388	-57
60.0	2445	2388	-57
62.5	2445	2388	-57
65.0	2445	2388	-57
67.5	2445	2388	-57
70.0	2445	2388	-57
72.5	2441	2388	-53
75.0	2433	2388	-45
77.5	2430	2388	-42
80.0	2421	2388	-33
82.5	2420	2388	-32
85.0	2380	2388	8
87.5	2276	2388	112
90.0	2245	2388	143
92.5	2191	2388	197
95.0	2182	2388	206
97.5	2161	2388	227
100.0	2086	2388	302

Table 2 – impact of lentil price change on cropping pattern (ha)

lentil price	Rainfed wheat	Flood wheat	Sprinkler wheat	Rainfed barley	Flood barley	Sprinkler barley	Flood cotton	Sprinkler cotton	Drip cotton	Rainfed lentil
2.5	4037	140232	6694	0	186332	17556	71986	3261	7322	0
5.0	4037	140232	6694	0	186332	17556	71986	3261	7322	0
7.5	4037	140232	6694	0	186332	17556	71986	3261	7322	0
10.0	4037	140232	6694	0	186332	17556	71986	3261	7322	0
12.5	4037	140232	6694	0	186332	17556	71986	3261	7322	0
15.0	4037	140232	6694	0	186332	17556	71986	3261	7322	0
17.5	4037	140232	6694	0	186332	17556	71986	3261	7322	0
20.0	4037	140232	6694	0	186332	17556	71986	3261	7322	0
22.5	4037	140232	6694	0	186332	17556	71986	3261	7322	0
25.0	4036	140232	6694	0	186332	17556	71986	3261	7322	1
27.5	4036	140232	6694	0	186186	17553	71986	3261	7322	149
30.0	4036	140232	6694	0	183316	17443	71986	3261	7322	3129
32.5	4036	138101	6694	0	175354	13646	71986	3261	7322	17019
35.0	4036	129191	4655	0	175354	13551	71986	3261	7322	28063
37.5	4036	117996	4507	0	154979	13120	71986	3261	7322	60214
40.0	4036	117996	4507	0	142447	12117	71986	3261	7322	73748
42.5	4036	117994	4507	0	128525	12117	71986	3261	7322	87672
45.0	2711	116457	4507	0	127131	12117	71986	3261	7322	91927
47.5	2711	115367	4507	0	123610	11283	71986	3261	7322	97373
50.0	2711	114758	4507	0	122795	11283	71986	3261	7322	98798
52.5	2711	114058	4507	0	122795	11283	71986	3261	7322	99497
55.0	2711	114058	4507	0	122795	11212	71986	3261	7322	99567
57.5	2711	113648	4507	0	121319	11208	71986	3261	7322	101458
60.0	2711	113552	4507	0	121319	11208	71986	3261	7322	101554
62.5	2711	113555	4507	0	121319	11202	71986	3261	7322	101558
65.0	2711	113555	4507	0	121319	11187	71986	3261	7322	101573
67.5	2711	113555	4507	0	121319	11187	71986	3261	7322	101573
70.0	2711	113557	4507	0	121319	11183	71986	3261	7322	101575
72.5	2711	113524	4507	0	121319	11183	71798	3261	7322	101796
75.0	2711	113436	4507	0	121319	11183	71366	3261	7322	102317
77.5	2711	112933	4507	0	121319	11183	71366	3261	7322	102820
80.0	2711	112791	4507	0	121319	11183	70917	3261	7322	103409
82.5	2711	112775	4507	0	121319	11183	70863	3261	7322	103480
85.0	2711	109723	4507	0	121319	11183	69406	3252	7322	107998
87.5	2711	109723	4507	0	121319	11183	63132	2060	7322	115463
90.0	2711	109723	4507	0	121319	11183	60905	2060	7322	117691
92.5	2711	109125	4507	0	121319	11183	57943	1494	7322	121817
95.0	2711	109125	4507	0	121319	11183	57347	1489	7322	122417
97.5	2711	109125	4507	0	121319	11183	56183	1131	7322	123940
100.0	2711	108371	4507	0	121319	11183	51577	1112	7322	129319

Table 3 – impact of chickpea price change on water use and balance (millions CM)

chickpea price	water use	water availability	water balance
2.5	2793	2388	-405
5.0	2793	2388	-405
7.5	2793	2388	-405
10.0	2793	2388	-405
12.5	2793	2388	-405
15.0	2793	2388	-405
17.5	2793	2388	-405
20.0	2793	2388	-405
22.5	2793	2388	-405
25.0	2793	2388	-405
27.5	2793	2388	-405
30.0	2793	2388	-405
32.5	2793	2388	-405
35.0	2773	2388	-385
37.5	2755	2388	-367
40.0	2711	2388	-323
42.5	2692	2388	-304
45.0	2690	2388	-302
47.5	2634	2388	-246
50.0	2633	2388	-245
52.5	2626	2388	-238
55.0	2626	2388	-238
57.5	2626	2388	-238
60.0	2612	2388	-224
62.5	2600	2388	-212
65.0	2554	2388	-166
67.5	2518	2388	-130
70.0	2504	2388	-116
72.5	2470	2388	-82
75.0	2470	2388	-82
77.5	2468	2388	-80
80.0	2468	2388	-80
82.5	2464	2388	-76
85.0	2457	2388	-69
87.5	2457	2388	-69
90.0	2457	2388	-69
92.5	2454	2388	-66
95.0	2452	2388	-64
97.5	2452	2388	-64
100.0	2451	2388	-63

Table 4- impact of chickpea price change on cropping pattern (ha)

chickpea price (SP/kg)	Rainfed wheat	Flood wheat	Sprinkler wheat	Flood barley	Sprinkler barley	Flood cotton	Sprinkler cotton	Drip cotton	Rainfed chickpea
2.5	4037	140232	6694	186332	17556	71986	3261	7322	0
5.0	4037	140232	6694	186332	17556	71986	3261	7322	0
7.5	4037	140232	6694	186332	17556	71986	3261	7322	0
10.0	4037	140232	6694	186332	17556	71986	3261	7322	0
12.5	4037	140232	6694	186332	17556	71986	3261	7322	0
15.0	4037	140232	6694	186332	17556	71986	3261	7322	0
17.5	4037	140232	6694	186332	17556	71986	3261	7322	0
20.0	4037	140232	6694	186332	17556	71986	3261	7322	0
22.5	4037	140232	6694	186332	17556	71986	3261	7322	0
25.0	4037	140232	6694	186332	17556	71986	3261	7322	0
27.5	4037	140232	6694	186332	17556	71986	3261	7322	0
30.0	4036	140232	6694	186332	17556	71986	3261	7322	1
32.5	4036	140232	6694	186332	17556	71986	3261	7322	1
35.0	4036	140232	6694	178660	17556	71986	3261	7322	7673
37.5	4036	138343	6694	175572	17144	71986	3261	7322	13062
40.0	4036	133116	4655	175572	13563	71986	3261	7322	23908
42.5	4036	129543	4655	175572	12782	71986	3261	7322	28262
45.0	4036	129543	4578	175171	12782	71986	3261	7322	28740
47.5	4036	118347	4507	175171	12781	71986	3261	7322	40008
50.0	4036	118347	4507	174953	12768	71986	3261	7322	40239
52.5	4036	116810	4507	174953	12768	71986	3261	7322	41776
55.0	4036	116810	4507	174951	12768	71986	3261	7322	41779
57.5	4036	116810	4507	174951	12768	71986	3261	7322	41779
60.0	4036	116755	4507	170247	12766	71986	3261	7322	46540
62.5	4036	116755	4507	166476	12764	71986	3261	7322	50313
65.0	4036	116755	4507	151525	11933	71986	3261	7322	66094
67.5	4036	116755	4507	139246	11933	71986	3261	7322	78374
70.0	4036	116755	4507	135323	10931	71986	3261	7322	83299
72.5	4036	116755	4507	123909	10931	71986	3261	7322	94713
75.0	4036	116755	4507	123909	10931	71986	3261	7322	94713
77.5	4036	116345	4507	123909	10931	71986	3261	7322	95123
80.0	2711	116314	4507	123909	10931	71986	3261	7322	96479
82.5	2711	115799	4507	123610	10931	71986	3261	7322	97293
85.0	2711	114603	4507	123610	10931	71986	3261	7322	98489
87.5	2711	114603	4507	123610	10931	71986	3261	7322	98489
90.0	2711	114603	4507	123610	10931	71986	3261	7322	98489
92.5	2711	113903	4507	123610	10931	71986	3261	7322	99188
95.0	2711	113903	4507	123182	10931	71986	3261	7322	99617
97.5	2711	113903	4507	123182	10931	71986	3261	7322	99617
100.0	2711	113903	4507	123182	10931	71931	3261	7322	99671

Table 5– impact of introducing cumin on water use and balance (millions CM)

cumin price	water use	water availability	water balance
2.5	2793	2388	-405
5.0	2793	2388	-405
7.5	2793	2388	-405
10.0	2793	2388	-405
12.5	2793	2388	-405
15.0	2793	2388	-405
17.5	2793	2388	-405
20.0	2793	2388	-405
22.5	2793	2388	-405
25.0	2793	2388	-405
27.5	2793	2388	-405
30.0	2793	2388	-405
32.5	2793	2388	-405
35.0	2792	2388	-404
37.5	2792	2388	-404
40.0	2792	2388	-404
42.5	2752	2388	-364
45.0	2714	2388	-326
47.5	2703	2388	-315
50.0	2616	2388	-228
52.5	2614	2388	-226
55.0	2606	2388	-218
57.5	2603	2388	-215
60.0	2594	2388	-206
62.5	2594	2388	-206
65.0	2594	2388	-206
67.5	2594	2388	-206
70.0	2590	2388	-202
72.5	2579	2388	-191
75.0	2579	2388	-191
77.5	2526	2388	-138
80.0	2470	2388	-82
82.5	2412	2388	-24
85.0	2412	2388	-24
87.5	2406	2388	-18
90.0	2406	2388	-18
92.5	2406	2388	-18
95.0	2401	2388	-13
97.5	2393	2388	-5
100.0	2385	2388	3

Table 6– impact of introducing cumin on cropping pattern (ha)

cumin price	Rainfed wheat	Irrigated wheat	Irrigated barley	Irrigated cotton	Rainfed cumin
2.5	4037	146927	203887	82569	0
5.0	4037	146927	203887	82569	0
7.5	4037	146927	203887	82569	0
10.0	4037	146927	203887	82569	0
12.5	4037	146927	203887	82569	0
15.0	4037	146927	203887	82569	0
17.5	4037	146927	203887	82569	0
20.0	4037	146927	203887	82569	0
22.5	4037	146927	203887	82569	0
25.0	4037	146927	203887	82569	0
27.5	4037	146927	203887	82569	0
30.0	4037	146927	203887	82569	0
32.5	4037	146927	203887	82569	0
35.0	4037	146927	203578	82569	309
37.5	4037	146927	203473	82569	415
40.0	4037	146927	203465	82569	422
42.5	2712	145038	192412	82569	14689
45.0	2712	144864	178306	82569	28969
47.5	2712	142473	178538	82569	31128
50.0	2712	133845	163265	82569	55029
52.5	2711	133845	162698	82569	55597
55.0	2711	133309	161186	82569	57645
57.5	2711	132757	161180	82569	58202
60.0	2711	131220	160751	82569	60168
62.5	2711	131220	160736	82569	60184
65.0	2711	131165	160736	82569	60239
67.5	2711	131137	160731	82569	60271
70.0	2711	131049	160731	82380	60548
72.5	2711	130592	160731	81948	61437
75.0	2711	130592	160731	81948	61437
77.5	2711	130431	145783	81500	76994
80.0	2711	127196	133504	81500	92509
82.5	2711	116001	132501	81500	104707
85.0	2711	116001	132501	81500	104707
87.5	2711	115402	132501	81354	105452
90.0	2711	115402	132501	81354	105452
92.5	2711	115402	132501	81354	105452
95.0	2711	114647	132501	81354	106207
97.5	2711	113586	132501	81210	107411
100.0	2711	113586	132501	80697	107924