IS WATER TARIFF REFORM POSSIBLE IN INDIA? THE CASE OF HARYANA PRODUCERS

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Abstract:

Since 1991 India is undertaking a process of liberalization of the agricultural sector as part of a structural adjustment program. This process will strongly affect the irrigation patterns because it will induce a payment for the electricity used for pumping. Can farmers react positively to a change in water costs policies which might imply changes in the balance between activities within the production systems? Will this policy increase structural problems? Will it have a positive or negative impact on food security? In this paper, a mathematical model is used to simulate farmers reactions to different water policy scenarios in Haryana (Northern part of India) and analyze their impact.

This type of policy will have a low but positive impact on the expenditures of the Electricity Board and the Haryana State, but it will hinder farmer's income (in some cases even under the minimum standards) and increase the risk faced by farmers, due to the higher costs. Also, the rural population might confront lower nutritional intake, and the condition of the water resource might not be improved. In order to prevent complex and sometimes unfair impacts for the farmers, a water price policy will require "adjusted" tariffs according to the category of farmers.

Keywords: India, agricultural policies, water policies, simulation models

Introduction

Irrigation is an age-old practice in India and a powerful mean for stabilize, even increase agricultural production, and thus attain self-sufficiency in food grain production. Consequently, major, medium (canal) and minor (bore- and tube well) irrigation projects were implemented since the independence, allowing India to rank second in the world after China in terms of net irrigated area to attaint 45,5 m.ha in 1991-92, representing 32,3% of the net sown area (CMIE, 1993). If the irrigation system, being one of the components of the Green revolution, allowed to attaint self-sufficiency in food grains productions, it also brought numerous undesirable effects such as water wastage, water logging, soil salinity, etc.

Irrigation has been state supported, in the form of direct subsidies and low interest loans (R.N. Ghatak, Katar Singh, 1994). Indian authorities spend annually about Rs. 5,000 crores for the development of new major and medium irrigation capacity (Dhawan, 1997), which does not take into account the expenditure for minor surface irrigation developments. This implies that since the Independence, India might have spent more than Rs. 45,000 crores on different water projects. Besides, the agriculture sector consumed (mainly for irrigation purposes) more than 30% of total power consumption in 1993-94 (Economic Survey, 1995-96). The opportunity cost of electricity is about Rs. 9-14 per KWH, but Indian farmers are hardly paying 15 to 30 paise per KWH of power (Dhawan, 1997). This situation is hardly sustainable. On one hand, it is difficult to raise the current electricity prices at the farm level, without provoking social unrest. On the other hand, the Indian society might not accept to continue the implicit and explicit resource transfer towards agriculture.

Simulation models can help in the process of evaluating benefits, costs and acceptability of alternative policy scenarios as well as their environmental and socioeconomic impacts. They are based in the representation of the agro-social-economic context, the numerous actors concerned as well as their complex interactions, and the trade-off between private and social objectives. The Multilevel Analysis Tool for Agriculture (MATA, Gérard et al.1994) appears to be adequate for the objective of evaluating water tariffs in India and their impacts on farmers, production, and State expenditures, in order to retablish the balance of the public expenditure or the recovery of the debts of some institutions like the National Electricity Board.

Haryana, a representative region of Indian production areas

When analyzing the self-sufficient aspects in the Indian agricultural policy, the selection of a region representative of the production aspects is driven to the northern part of the country (Trans-Gangetic zone, zone VI). In this area, the region of Haryana is a good example of the advantages and problems in the area:

It is one of the most important producing areas, with the Punjab, of rice and wheat; it best represents the major concern of the Government to maintain an adequate national productive level in the context of liberalization and privatization.

It includes 3 large zones: arid, semi-arid and dry subhumid. The two large semi-arid and arid zones (respectively with 561 and 320 mm/year in average) are representative of the two main systems of production: 1) the system of wheat/rice which covers a large part of the alluvial zones in the north of India, with private tube well and well irrigation systems, in some cases allowing excessive water pumping and thus important drops in the level of the water table; and 2) the more diversified system comprising the traditional food crops (millet, sorghum, wheat) and cash crops (cotton, rapeseed), characteristic of the arid zones of a large part of India, accompanied by canal

irrigation and generating problems of soil salinity. In the small dry subhumid area, in the northen part of Haryana, with annual rainfall of about 891 mm, the main crops are food grain (wheat/rice) and sugarcane. In general, the increase of net irrigated area is mainly due to intensification of groundwater use, although canal development is also significant.
Finally, reliable data is available for the region, based on numerous surveys carried out by the ICAR (Indian Agricultural Research Institute).
Irrigation is essential in the arid and semi-arid zone and thus any policy affecting water pricing will have a strong impact. The analysis will then focus on these two zones. The arid zone can be represented by two districts : Hisar and Bhiwani, where population density is of 236 and 180 inhabitants/km^2 respectively, with an average in both cases of 17,3% of land allocated with fodder crops and 67% with cereals & pulses. In Hisar district, canal irrigation is more important, and wheat and cotton are predominant. In the district of Bhiwani salinity problems badly affect production possibilities, limiting the cropping alternatives to wheat, rapeseed and millet/bajra. In the semi-arid zone, the Karnal district is representative of the characteristics in the region, higher density of population (355 inhabitants/km^2), more than 87,3% of the land is cultivated with near 70% in cereals and pulses and 9% in fodder crops, featuring crop rotation systems - wheat/rice - requiring high use of inputs (fertilizer) and capital for irrigation.
A typology of the different farmers in each area was identified with the data obtained through a survey of 120 families in 12 villages that included different actors concerned by agriculture production (owners, tenants and landless farmers). The main criteria differentiating the actors, identified through Multiple Correspondence Analysis, is the access to production factors, explained by land endowment and by the irrigation type (13 and 7.22% of the variability between farmers) . The analysis also reveals a close relationship between ownership of a private well and tractor with total cultivated land area. Two groups of farms can thus be identified: 1) small farms with less than two hectares and low investment in agricultural equipment and capital (irrigation, a single buffalo); and 2) medium and large farms of more than 6 hectares, “capital intensive” because of the technological level (equipment, more than 2 private tube wells, certified seeds for rice, utilization of zinc in soils). A second discriminating factor concerns the predominant cropping system: wheat/rice in the semiarid region and wheat/cotton in the arid region, associated with two distinct irrigation systems, private tube-well or public canal respectively. This typology implies similar production structures in both areas, strongly affected by the irrigation system and the agro-ecological production possibilities. Further analysis showed a very strong correlation between the initial endowments of the farmers (means of irrigation, area cultivated, tractor) and the social characteristic of the head of the household (caste, educational level). The small and medium farms held by a majority of heads of household of low caste whose level of education rarely exceeds primary school. On the contrary, the large farms are held mainly by heads of household belonging to high castes in the Indian social system and possessing secondary education.
The analysis confirms the importance of the land inheritance as explaining factor of the level of intensification (irrigation system, implements, etc.). This strong determinant explains not only the difficulties to implement a land reform but also questions the viability of marginal and small farms, which are strongly affected negatively by the inheritance sharing processes; increasingly scattering of the land between generation. Besides, their viability will also be affected if farmers are forced to pay a more realistic price for the water they use for irrigation. Which farmers can subsist and which can be excluded from the production system by alternative water tariff policies ? A simulation model was developed to try to provide some insight on farmers' possible

responses through the representation of their behavior.

A detailed description of farmers' behavior

The simulation model that will be used to describe the possible responses of farmers to alternative water tariff policies will be based on a detailed representation of farmers' behavior (Annex 1). The principal assumption is that there is no automatic adjustment between agricultural supply and demand, and when confronted to policy incentives, farmers' response will not forcibly allow to attaint automatically an equilibrium between supply and demand. At the moment of making up their minds, farmers evaluate the different possibilities based on yield, price and costs expectations, expectations that might not be fulfilled at the moment of harvesting. This implies a difference between expected and actual income, which will forcibly affects farmers' investment capacity and their decision making in the following seasons. This is particularly true for the case of India, where production is carried out seasonally and the choice of the cropping system is adjusted according to the (lack of) actual income in the previous seasons. In particular, during the third season (after the rainy and the dry ones), farmers can maintain land in fallow or cultivate with sorghum, cow peas (for fodder purposes) or sunflower. In the latter case, the reason resides in increasing the return from the land or in the compensation for a low wheat yields in the previous season. In the model these processes are represented explicitly to describe with a certain level of precision the actual changes taking place over time, and compare production trends in the medium-term as a consequence of the simulated policies.

Three objectives are pursued with the model: 1. to reproduce farmers' individual economic decision making process based on an optimization procedure subject to individual and regional constraints, 2. to represent transfers between farmers and 3. to consider different technologies for each crop in order to represent farmers' adaptability under the different scenarios. For each growing season, the model represents the individual behaviors in each of the areas as well as the aggregate outcome.

The choice between crops is a function of climatic conditions, irrigation system, monthly water stock possibilities and fodder requirement of animals. Technical coefficients for each crop are included for each source of traction (tractor, bullock, etc.), seed variety and level of fertilization. Cattle activities, an important source of income, manure, traction, consumption and reserve of cash, are differentiated by categories (specie of animal, purpose, age). The decision to maintain the animals in the farm is a function of expectations on fodder availability, the value of the animals at the end of the season, their productivity and farmers' cash requirements. For each type of female (buffalo, cattle, crossbred), milk productivity responds to the animal diet (dry matter contents as well as fodder and concentrates proportion) and the cost of opportunity of each type of feed (green and dry fodder and different concentrates available on the market). Annual changes in livestock are a consequence of the natural reproduction rate as well as of sales and purchases.

Each type of farm have access to different sources of credit to finance its activities or its social requirements. However, the duration of the credit depend on the forecasted uses: short-term for seasonal inputs or to carry out the activities during a bad season; medium term credit for livestock investment; and long term credit for heavy investments (like tube-well, tractor). Each type of credit requires a certain level of guarantees and is limited at the regional level based on national governmental planning policies. The formal credit circuit, which prevails in Haryana, implies a linkage between the credit form and its uses and an official interest rate.

A minimum level of consumption (calculated according to the minimum recommended intake of calories and protein per capita in India) is imposed in the model to reflect requirements and preferences of the household. These requirements can be overcame either through self production or purchases from the market. Farmers' attitude regarding agronomic and economic risk is represented through the Target MOTAD methodology (Tauer, 1983), which introduces a set of minimum income constraints, allowing a deviation according to farmers' attitude.

The objective function links explicitly the short-term liquidity goal with the long-term household objectives of increasing the level of saving and assets, according to relative prices between livestock and tractor at the market value and interest rate of saving (it is supposed that livestock and tractor are the main assets besides the land). The surplus can be used to increase the productive capacities of the farm (strategy of accumulation) or to improve the short-term return by increasing the level of input uses such as fertilization or fodder (strategy of maximization of short-term cash flow availability) as a function of expected return from each seasonal alternative, the possible interest rate of saving, the minimum level of income necessary to have access to credit and thus finance a new asset.

Farmers interact among themselves through the exchange of manpower, manure, traction animals or hours of tractor. These exchanges take into consideration the "actual" local availability of resources as well as the social "rules" in the society, i.e. medium farms can not employ agricultural workers from large farms, due to the massive representation of high cast individuals among the later. Also, in large farms, few women participate to the agricultural work.

Finally, even if optimization is based on expected prices, the estimation of farmers' income is estimated at the end of each growing season with "observed" prices. Actual prices were used for the reference year 1998 (observed data during the survey, 1998) In the following years, prices in the simulation are supposed to remain constant in order to represent farmers' difficulties to forecast any price change as well as to reflect their optimist view (according to them, the Indian government can not give up on them!).

The model is calibrated representing five farm types in each zone. The exogenous parameters are land, family labor, equipment (tractor, tools), livestock characteristics (species, age, sex, etc.) endowments and irrigation (system and access). The initial dry fodder and cereal stocks as well as cash flow and saving deposits are also considered; as determined by the survey. It is extremely difficult to validate simulation models. In the case of the present exercise, two parameters were checked: the degree of accuracy of simulated results (land and labor allocation as well as technical choices) with observed data and the stability of the model results in the long run, *ceteris paribus*. Except for some minor deviation from the observed results (in particular a slight deviation of fodder area variable due to the lack of consideration of the boundaries of the plots – source of pasture- and the post-harvesting losses), the model reproduces accurately farmers' choices in the two agro-climatic areas for the main parameters (cropping system, use of mechanical traction, fertilizer used per ha, dairy activity). The model is therefore able to provide some useful insights on how farmers might react when confronted with different policies from the actual ones.

Responses to water tariffs policies.

In a context of liberalization, several changes will affect the Indian agricultural sector in the near future. As part of the Structural Adjustment Program, the Government of India is encouraged to decrease subsidies for fertilizers, irrigation and price crops. Even if the fertilizer price policy has been modified five times since 1991 and nowadays only the nitrogen component of fertilizers is still subsidized, the water tariff policy raises large debates, with few "concensus" being attained. In the case of irrigation done through well pumping, the cost of electricity required is only limited to the payment of a tax based on the pump power (without been linked with the electricity consumption and/or water use). This under-paying of water has encouraged the over-development of ground-water based irrigation, and consequently a large government deficit. In the case of Haryana, where the State Electricity Board would register a deficit of Rs. 593,98 crore without government subsidies in 1997-98 (Annual Accounts of the Boards, 1997-98), Dhawan (1997) estimated that: "Indian farmers are hardly paying 15 to 30 paise per KWH of power actually consumed by them, though true resource cost of supplying power to them in the countryside could be Rs. 3.50-4 per KWH". In the case of canal irrigation, the cost of access reflects neither the social cost of water supply nor the operation and maintenance cost of the irrigation infrastructure. The annual cost of canal irrigation is estimated to have been in 1992-93 of approximately Rs. 5,000 crore for a surface of 22 million cropped hectares (16,6 millions hectares in net irrigated area terms) (National Account Statistics). These statistics suggest that the actual resource cost of supplying irrigation through canals averages about Rs 2,277 per crop hectare. However, farmers only paid in the average Rs. 151 per hectare and season. In Haryana, the survey reveals some rates close to Rs. 73 per hectare. Therefore Dhawan suggests a more reasonable desired tariff of Rs. 1100 per irrigated hectare, which would allow to cover a almost half of the resource cost per hectare. In the both cases, the reason to maintain the underpricing is the fear of producing social and political unrest due to the increase of production costs but also the risk of decrease the degree of self sufficiency in food grains. The simulated scenarios in this paper are based on the current stakes being discussed concerning the elimination of explicit and implicit water tariff subsidies through the application of a more realistic price which would imply a cost of around Rs. 0,3/m^3 of water.

In this paper, different water rates for well pump (from Rs. 0,1/m^3 to Rs. 1,0/m^3) will be simulated to identify their impact on different determinant variables, which might differ at each farm level. This analysis will allow to determine the maximum level of water taxation that is acceptable for the each of them according to their characteristics. To simplify, only two of these scenarios will be used (Rs. 0,3/m^3 and Rs. 0,6/m^3) to analyze the impact of water tariff policies at the regional level. Concerning the canal irrigation costs, two scenarios are tested in the arid area: Rs. 1100 and Rs. 2200 per irrigated hectare. The simulations were undertaken for a period of five years in order to take into account the eventual adjustment of the cropping systems to the simulated policies.

The results show that in the semiarid area, all the farmers will be affected by the water tariffs. Even if farmers can maintain paddy if the water tariff does not exceed Rs. 0,4/m^3; they switch to cotton at a tariff of Rs. 0,5/m^3 because it requires less irrigation. The impacts are more important when the individual cash flows are analyzed. Small and medium farms can be rapidly affected by an increase of water tariffs. The former have very low flexibility: with a tariff greater than Rs. 0.2/m^3, they will not be able to provide for the under minimum level of survival (Rs. 5000/year). Medium farms can stand higher tariffs, but at the level of Rs. 0,4 and 0,5/m^3 they will obtained half the actual cash flow, and they will approach the minimum level of survival for tariffs of Rs. 0,8/m^3 and more (Graph 2). The semi medium and large farms seem to be able to stand higher increases of water tariffs although strong variations of their cash flow after Rs. 0,6/m^3 are observed, as a consequence of changes in the production choices (graph 3). The only farmers who will not suffer much from higher tariffs will be the marginal ones because they mainly rent the land and the water tariffs are paid by the land owner and also because their main source of their income comes form external hiring of their labor. However, the arrangements concerning land rent might be modified if the water tariffs are increased, affecting thus the marginal farmers. As expected, the larger farmers will be able to cope better with higher water tariffs. This is confirmed by the analysis of the different switching points at 80% of the level of the actual cash flow (Graph4). If the objective of rice self-sufficiency is considered, the scenarios show that a water tariff of Rs.0,4/m^3 will not affect production (graph 5).

Graph 3 and 4

The results of these simulations suggest that it will be difficult to fix only one water tariff for all the farmers. One possibility could be to measure and apply a tariff to water, or even better, electricity consumption. Another possibility would be to fix different levels of water tariff according to the amount of land owner by farmers. However, the former would imply large expenditures for installation and maintenance of water or electricity counters and the later could reinforce understated declarations of land ownership (as it was observed during the land policy implementation[1]). In areas where financial resources are scarce, only information and sensitization of the local authorities (Panchayat) on the future risks for the society as a whole could push forward mechanisms allowing to avoid false declarations. Also, tariffs should be annually adjusted, to adapt them to changes in crop prices and inputs.

In the arid area, the simulations show that the impact of alternative water tariffs will be less spectacular, mainly due to two reasons: the access to canal irrigation infrastructure can not be avoided and thus the tariff has to be paid, and few technical alternatives or crops are possible, beside cotton or groundnut in this area. The effects are important though on farmers' cash flow. Even if the effects are relatively more important for larger farmers, it would be less acceptable for the small farmers, because they almost reach the minimum level of cash flow for survival.

Graph 6

At the regional level, the aggregated direct impact on farmers' revenues (which does not take into account the revenues of the Electric company due to the increase in tariffs) are negative for all cases expect one, the case of water tariff Rs.0.3/m^3 scenario in the semiarid area, where well pump irrigation system is dominant. This is not explained by an increase in the areas of the main marketing crops (like paddy or wheat) but by: 1) an increase in the capital assets in the semiarid area, because farmers can keep their male calves for draft power or only in a purpose of capitalization which in the long run provides for higher revenues; 2) a reduction of small farmers' purchases of fodder for animals given an increase in fodder area and 3) an increase in the production and sale of more milk (2,8% and 1,8% respectively). Paradoxically, this scenario indicates that this level of tariff can induce a reorganization of factors use for a more efficient outcome.

Graph 7

The urban consumers will be indirectly affected by water tariff policies: the supply of irrigated crops will decrease and probably their price will increase. However, the effects can be more negative on rural consumption where the sources for alternative revenues are more limited. The graph 8 shows an unbalance consumption for the consumption between wheat and rice.

Graph 8

Finally, the water tariff of Rs. 0,3 /m^3 will have no impact on the milk productivity (one of the

[1] After the Independence, land reform conducted to large land splitting between members of the family. Therefore, few proportion of land had been redistributed to landless or small farmers.

principal sources of protein) because of substitutions in the sources of fodder in the animal diet: between dry and green fodder in the semiarid area and between pasture and green fodder in the arid area. The Rs. 0,6 /m^3 scenario shows a strong negative effect due to irrigation requirements of fodder crops (specially for berseem).

Graph 9

It is observed significant impacts of the different water policies scenarios on the financial outcome of the Haryana Electricity Board, on the water consumption and on farmers' costs. In graph 10, for the water tariff of Rs. 0.3/m^3, farmers' revenue would be very affected. The overuse of water does not change because of the maintain of the cropping system "wheat/rice" in this area. Only the public expenditures (subsidies) would decrease. At a water tariff of Rs. 0.6/m3, farmers' electricity charges are stabilized at the level of "reference situation" but this is due to a strong decrease in water use, which could have a positive impact on the environment. In reality, farmers, Electricity Board and Haryana State are losers: 1) farmers' revenue would be affected with the substitution of paddy by cotton, 2) The Electricity Board would loose its income, unable to maintain its infrastructure without water consumption and 3) Haryana State would be obliged to compensate the decrease of paddy production by import or/and more subsidies for consumers. These results show the solution for the water tariff problem is not easy and that it will require arbitrages between maintaining production (and which production by the way), assuming a reasonable use of water (in particular for environmental purposes) and entertaining the Electricity Board functions.

Graph 10

Conclusion :

Increasing water tariffs can be a helpful, and eventually unavoidable policy to relax budgetary constraints in some regions in India. The results indicate the need for an "adjusted" tariff fixation process, specially to adapt them to the different farm types and provide a less "unfair" or socially unacceptable impact. Politicians have to be aware that farmers will have to face a lower income level (in some cases even under the minimum standards) and higher risk due to higher costs. Finally the rural population might suffer from lower nutritional levels. The results also show that the better endowed regions from the agro-ecological viewpoint might be able to cope better with this policy. Are the politician willing to undertake this reform and in particular the social "ballot" costs ? Shall the present and future social and environmental pay-off be sufficient enough to push forward this water tariff policy ? Simulation can provide some hints for the policy makers, but the decision stays in the influence and political power of the different groups of actors involved and the willingness to avoid future externalities. But no public intervention in the field of water policy could compromise the sustainability of the system in the future although each water tariff policy creates new configuration of risk between the different actors and points of view (producers, Electricity Board, Government, water resource).

Appendix :

For each farmer, the level of each activity *j* ($x_{j,i}$) is limited by the amount of resources b_i:

(1) $$\sum_j a_{j,i}.x_{j,i} \leq b_i$$

where $a_{j,i}$ are the technical coefficients of each activity *j* for farm *i*.

Resources (bb) that can be hired in or out to other farmers, like labour, oxen traction, equipment, etc., for each type of farm *i* are represented as:

(2) $$\sum_j a_{j,i}.x_{j,i} \pm \sum_{j,k} aa_{j,i,k}.xx_{j,i,k} \leq bb_{j,i}$$

where *k* are the other types of farms, *aa* the technical coefficient of the activity and *xx* the level of use of the resource of farm *k* by farm *i* or of farm *i* by farm *k* . Then, the equilibrium between the resource supply and the demand is reached by:

(3) $$\sum_{j,i,k} aa_{j,i,k}.xx_{j,i,k}.n_i = \sum_{j,k,i} aa_{j,k,i}.xx_{j,k,i}.n_k$$

where *n* is the number of farms within each farm group. The transfers among farmers respect thus the "actual" local availability of the resources but also the social rules in the society.

The livestock demography is determined by the model according to a mortality rate -m(age)-, the specie sp_s and the age of each animal:

(4) $$bov(sp_s, age_{t+1}) = (1 - m(age_t)) * bov(sp_s, age_t)$$

The milk production function is determined according to the type of feed in quantity and quality (dry matter, metabolism energy and DCP). In order to alleviate the model, here it is only supposed the level of dry matter.

According to the total availability of credit in the region (Credtot) and the credit allocation by type of purpose, the optimal allocation ($Cred_{j,i}$) is determined by the model:

(4) $$\sum_{j,i} x_{j,i}.Cred_{j,i}.n_i \leq Credtot$$

The model takes into account a minimum level of consumption (*CalMin*) which is introduced as a constraint, reflecting preferences of the household in separated constraints, that can be overcome either through self production or through purchases (*Purch*) both affected by the number of calories and proteins (cal_n) given by each product.

(5) $$cal_{nj}.x_{j,i}.y_{j,i,ye} + purch_{j,i}.cal_{n,j} \geq CalMin_{n,i,ye}$$

For the attitude concerning economic risk, the method employed (6 & 7) is an application of Target MOTAD methodology (Tauer, 1983), which introduces a set of minimum income (*MinInc*) constraints allowing the possibility of deviation (*Dev*) from these minimum to quantify farmers' attitude (*Devtot*). This model based on minimizing the gap in net incomes has the advantage of representing the risk under the form of linear constraint.

(6) $$\sum_{j} y_{j,i,ye}.x_{j,i}.p_{j,ye} + Dev_{i,ye} \geq MinInc_{i,ye}$$

(7) $$\sum_{ye} Dev_{i,ye} \leq Devtot_i$$

The objective function tries to reproduce the goals of farmers within a framework reproducing individual and regional maximisation objectives. It contemplates the aggregation of the maximisation of the net income (9) (revenue less cost *co*) at the community level plus the cost-effectiveness of investment in live capital, which constitute a type of saving or precautionary reserve (*livestock*).

(10) $$MaxZ = \sum_{i} \left\{ \left[\sum_{j} [p_j.(y_{j,i}.x_{j,i} - cons_{j,i}) - co_{j,i} \right] + \left[\sum_{l} livestock_{l,i} \right] \right\}$$

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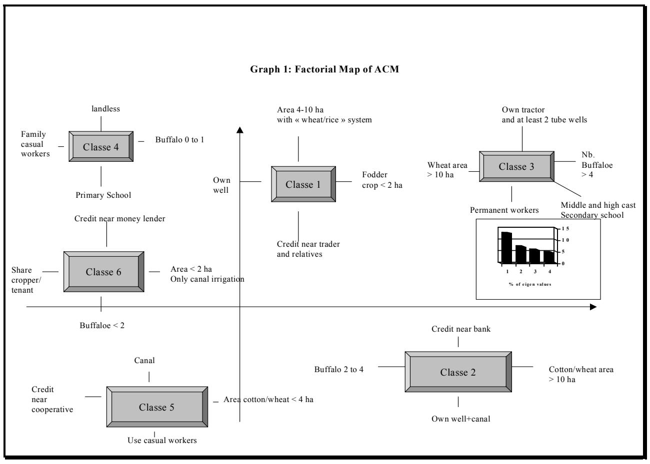
Appendices:
For each season:

Equations	Description
(1) $\sum_{ex,j} a_{j,i}.x_{ex,j} \leq b_i$	(1) Equation of constraint according to the avaibility of the resource at the regional level
(2) $\sum_{j} a_{j,i}.x_{ex,j} \pm \sum_{ex,k,j} aa_{j,i}.xx_{ex,k,j} \leq bb_i$	(2) Possibility of hiring in or out to other farmers for labor, oxen traction, equipment, etc.,
(3) $\sum_{ex,k,j} aa_{j,i}.xx_{ex,k,j}.n_{ex} = \sum_{k,ex,j} aa_{j,i}.xx_{k,ex,j,i}.n_k$	(3) The equilibrium between the resource supply and the demand. These transfers respect the "actual" local avaibility of the resources but also the social rules in the society.
(4) $Milk_{ex} = \sum_{sp,age>4years} y_{ex,sp,'female',age} * Ym_{sp,nut}$	(4) Milk production function determined according to the type of feed (nut) in quantity and quality (dry matter, metabolism energy and DCP).
(5) $\sum_{ex,i} x_{ex,i}.Cred_{ex,i}.n_i \leq Credtot$	(5) Optimal allocation of credit according to the total availability of credit in the region
(6) $cal_{nj}.x_{ex,j}.y_{j,ye} + purch_{ex,j}.cal_{n,j} \geq CalMin_{ex,n,ye}$	(6) Taking into account a minimum level of consumption, reflecting preferences of the household in separated constraints, that can be overcome either through self production or through purchases, both affected by the number of calories and proteins given by each product.
(7) $\sum_{j} y_{j,ye}.x_{ex,j}.p_{j,ye} + Dev_{ex,ye} \geq MinInc_{ex,ye}$ (8) $\sum_{ye} Dev_{ex,ye} \leq Devtot_{ex}$	(7 & 8) Equation of attitude concerning economic risk (Target MOTAD, Tauer, 1983).
(9) $MaxZ = \sum_{ex} \left\{ \left[\sum_{j} [p_j.(y_{ex,j}.x_{ex,j} - cons_{ex,j}) - co_{ex,j} \right] + \left[\sum_{sp,sex,age} \mathrm{y}_{\mathrm{ex,sp,sex,age}} \right] \right.$	(9) objective function within a framework reproducing individual and regional maximization objectives.

$x_{j,i}$: level of each activity j obtained with the input i; $a_{j,i}$: technical coefficients of each activity j
ex: type of farm; *k*: other type of farm
aa: technical coefficient of activity; *xx*: level of use of the resource of farm k by farm ex or of farm ex by farm k
m: mortality rate ; *f*: fecondity by specie, sex and age of the animal
sp: Specie (local caw, crossbred, buffaloe); *age:* age of each animal
Milk: milk production; *Ym*: milk yield per specie in function of the nutrient intake in dry matter, DCP, TDN; $y_{ex,sp,sex,age}$: livestock per specie, sex and age.
Credtot: total availability of credit in the region; *Cred*: demand of credit for the purpose i
CalMin : minimum level of consumption; *Purch*: purchases of products; cal_n : number of calories and proteins given by each product n, *y*: yield for activity j..
MinInc: set of minimum income ; *Dev:* possibility of deviation from the minimum; *Devtot*: farmers' attitude.
Co: Cost of production

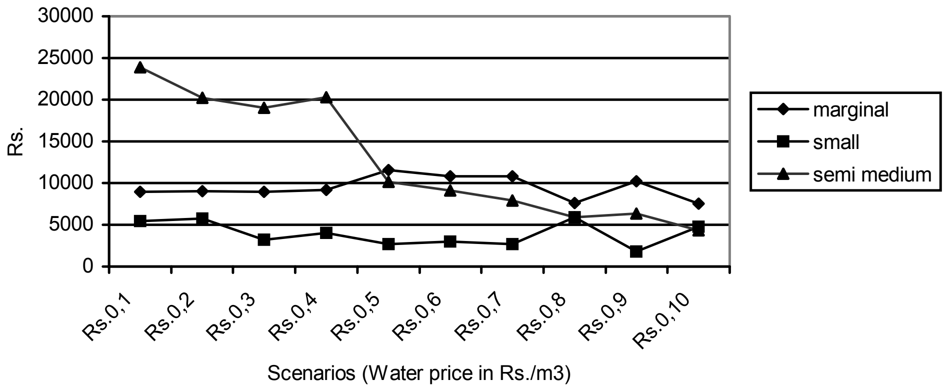
Between season:

Equations	Description
(10) $x_{ex,jp(j),pc+1} = x_{ex,jp(j),pc}$	(10) For perennial crops as sugarcane, transfer of planted land
(11) $WADISP_{ex,ir,irun,m} \leq \sum_{irun} (WAini_{ex,ir,irun,m} + WPUR_{ex,ir,irun,m}) * flow_{irun} + WA\mathrm{TR}\ AN_{ex,ir,m-1}$	(11) Monthly transfer of water
(12) $y_{sp,sex,age+1,pc+1} = (1 - m_{sp,sex,age,pc}) * (y_{sp,sex,age,pc} + ypurchase_{sp,sex,age,pc} - ysell_{sp,sex,age,pc})$	(12) Livestock demography
(13) $y_{sp,sex,age1,pc} = f_{sp} / 2 * y_{sp,female,>4years,pc-1}$	(13) Natural renewable of the livestock
(14) $C_{ex,j,pc} + STO_{ex,j,pc} + S_{ex,j,pc} = STO_{ex,j,pc-1} + P_{ex,j,pc-1} + PUR_{ex,j,pc}$	(14) Self-consumption et sale in season pc, stockage for the next period depends on production and stock in the previous season pc-1 and the purchase in pc
(15) $Feed_{f(j),pc} = f(t_j x_{ex,j,pc-1}) + STO_{ex,f(j),pc-1}$	(15) Avaibility of fodder according to the the cropping system and the stockage the previous season
Jp(j): perennial crops; *Pc*: season (three seasons are considering: the rainy, winter and summer season) *y*: livestock specified by the specie (*sp*), the sex (*sex*) and the age (*age*); *Ypurchase* and *Ysell*: purchase or sale of animal at the beginning of the season. *C*: family consumption of the product j : *STO*: stock of j and *S:* sell of the product j; *P:* production of j and *PUR*: purchase of j *Feed*: avaibility of fodder from the activity j; *t*: technical coefficient of transformation of j in feed type	

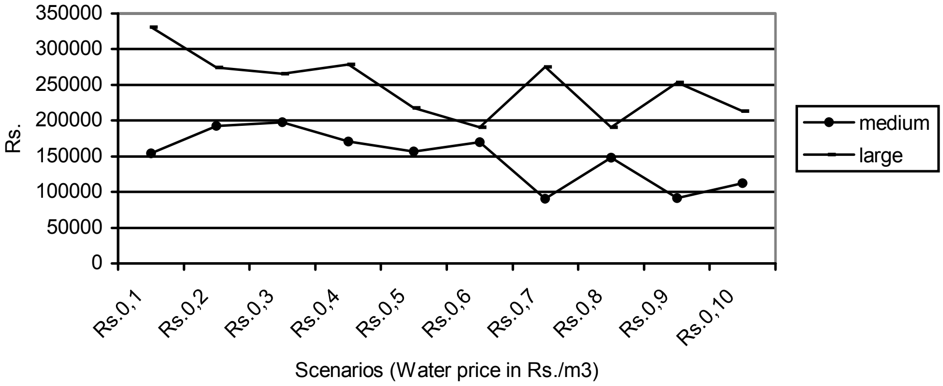


Graph 1: Factorial Map of ACM

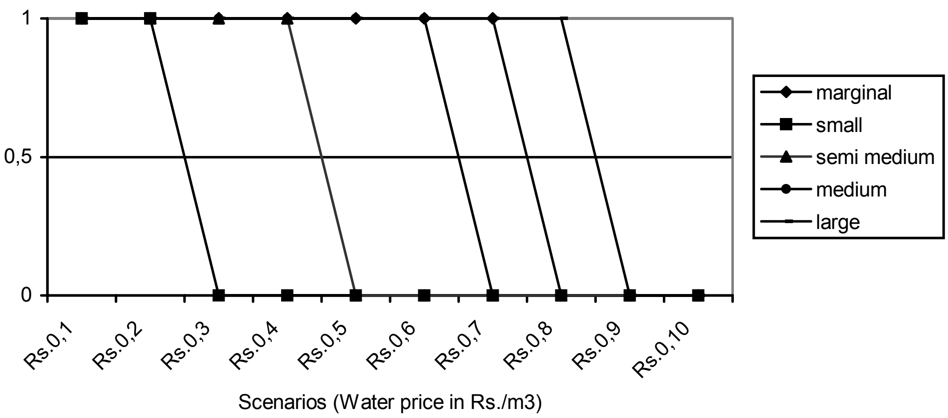
Graph 2: Impacts of water pricing policies on the level of cash flow for the different small types of farm (in Rs.)



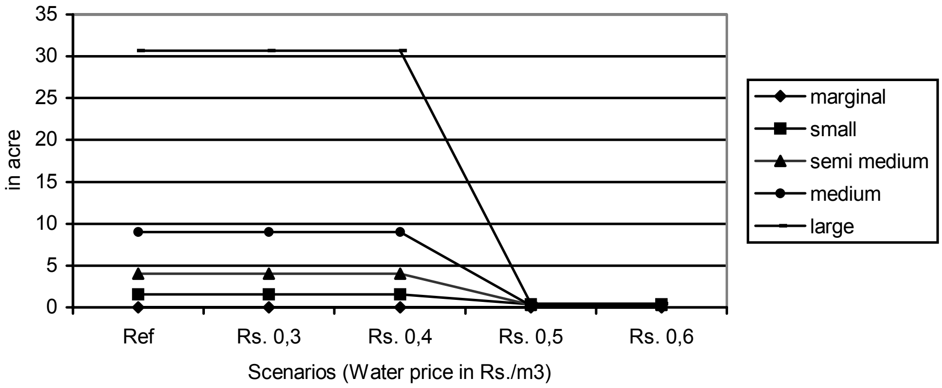
Graph 3 : Impacts of water pricing policies on the level of cash flow for the different medium types of farm (in Rs.)



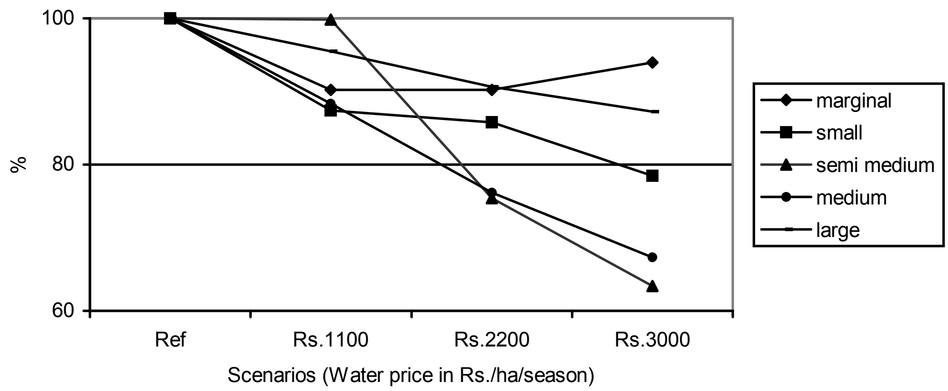
Graph 4 : Switching pont at 80% of cash flow in the semiarid region



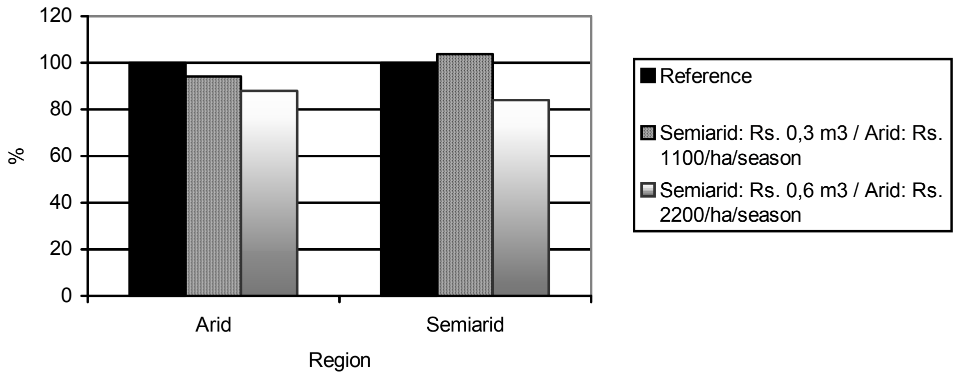
Graph 5 : Change of paddy area for the different scenarios of water tariff and for each type of farm (in acres)



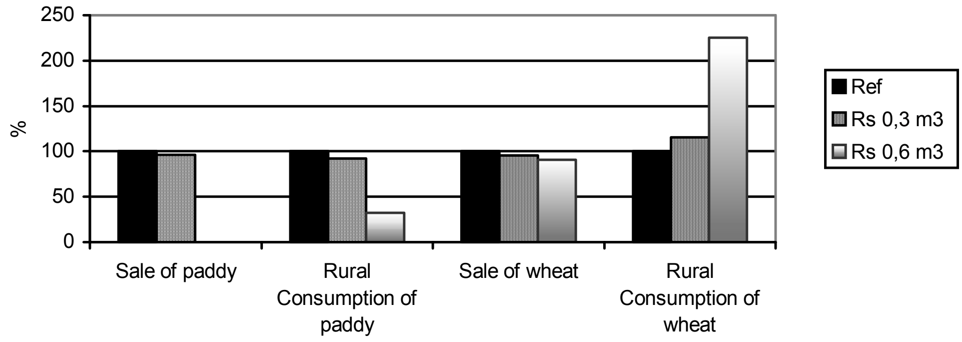
Graph 6 : Cash Flow Variation (Baseline =100) for the different scenarios of water policies (In Rs./ha)- Arid Area



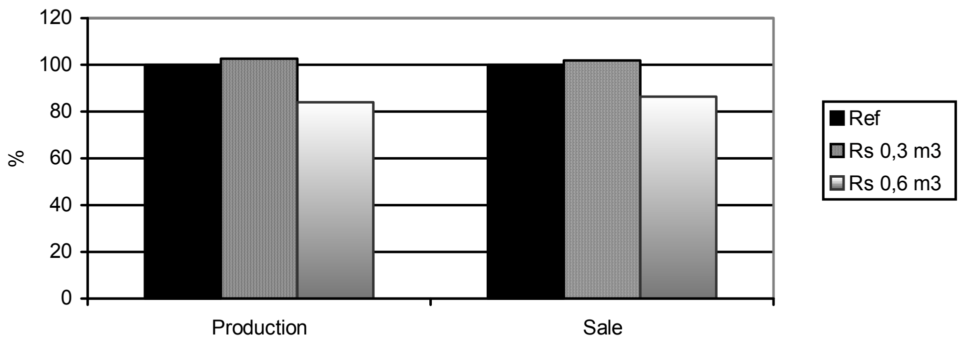
Graph 7 : Changes in regional farmers' revenus as a consequence of different policies over 5 years of simulation [% of deviation of the regional cumulated revenus over the 5 years of simulation]



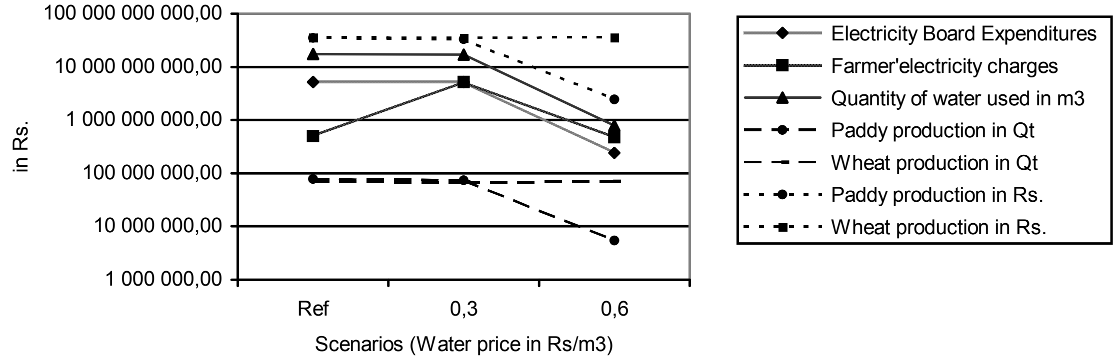
Graph 8 : Variation of regional sale and rural consumption of paddy and wheat for the different scenarios - Semiarid area (in %)



Graph 9 : Comparison between the milk production and the sale for the different scenarii- Semiarid area



Graph 10 : Regional impacts of different scenarios of water tariff for rural population, Electricity Board and State



Graph 10b : Comparaison between the public benefit and diffference of the regional rural revenue in the semiarid area for each scenarios