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Full Length Research Paper

Assessment of water resource allocation policies based on the principle of comparative advantage and a policy analysis matrix: A case study of Hamedan-Bahar Plain

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Comparative advantages of agricultural products were evaluated using the policy analysis matrix (PAM), to determine the combination of products according to market and shadow prices. Based on these evaluations, maximum amount for import virtual water was identified. Results showed that optimum cropping pattern in term of maximizing social benefits not only had the highest amount of benefits - 29160 USD but it also required much less water amount consumption in comparison with the two other cropping patterns.

Key words: Virtual water, policy analysis matrix (PAM), comparative advantage, social benefit, gross margin.

INTRODUCTION

Arid and semi-arid regions of Iran are faced with some fundamental challenges from insufficient water supply, unsuitable management and planning of water supplies as well as commercial policies on agricultural products. The limited opportunities for searching for new sources of water, the continuing increase in demand for water and inefficient water distribution clearly demonstrate shortcoming of this vital resource.

Water supply is limited largely because of budget limitations, increase cost of supply cost and the use of new resources. So new ways to manage the demand, water are being investigated and they focus on the efficient use of available water resources and commercial policies of agricultural products (Johansson et al., 2002).

Virtual water is a new term in the literature in the field relating to strategies for the efficient use of water resources. Virtual water was first defined as the water used to produce each unit of products (Allan, 1997). Transferring large amounts of food is easier than transferring huge quantities of water, so the exchange of fundamental goods is a way for national economies with water shortages to compensate for water storage. Virtual water, alongside that of local water provides the water requirements for a country (Allan, 1997), thus the concept of virtual water. The amount of virtual water exported by a country measured as the amount of discharge by an exporting country. Virtual water that is imported to destination countries is defined as the water quantity which is needed for production without its importing. Virtual water is an essential tool that helps to measure the actual water consumption of a country for agricultural products.

The determination of cropping patterns based on virtual water is a suitable strategy to manage crises of water shortage and to promote water use efficiency, especially in countries with dry climates where agriculture is dependent on irrigation. Thus, instead of using scarce water resource on crops that need a lot of water, putting pressure on the resource, a choice can be made to cultivate those crops that need less water. The exchange of virtual water inside countries, between countries and between continent can be used as a tool for improve water use efficiency worldwide, to address the problem

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environmental constraints of water security in water poor areas. In this way, appropriate locations can be determined for specific crops (Turton, 2000). Considering the amount of virtual water in foods are imported with the water in poor countries highlight the strong relationship between water shortage and dependence on food imports (Yang and Zehnder, 2002). Virtual water combines agricultural and economic concepts by emphasizing water as a key factor in production (Wichelns, 2001). Therefore, a region, province or a country that has high fluctuations in precipitation can considerably decrease its water consumption by importing some foods rather than attempting to produce it all. This fact forms the underlying substructure of the concept of virtual water promoting the exchange of food as a solution for more efficient water use and to balances water reserve in drought prone regions and countries with high precipitation.

Funing and Lonbo (2001) measured the comparative advantage in China`s grain production with the DRC. Result of the study showed that crops such as Japanese rice, sorghum, medium Indian rice, millet, and delayed maturing Indian rice were comparatively advantageous crops. Mohanty et al. (2002) researched the production efficiency of cotton in five states of India using the PAM. Results show that the second largest cotton producing state in India did not have the highest production efficiency in cotton. Kubursi (2005) studied the effect of government incentives to boost the production of major agricultural products in Lebanon. Results showed that these incentives had no specific effect on improving the allocation of inputs and production factors.

Mainuddin et al. (1997) used the multipurpose programming approach to determine an optimal cropping pattern and a strategy for sustainable exploitation of ground water. The goal of this objective function was to maximize net profit and increase acreage under cultivation. Raju and Kumar (1999) used the multipurpose programming to study the best adaptive irrigation plan. This considered three goals of net profit, agricultural production and employment. Results showed that the best adaptive plan had a net profit 8980 rupees; 3073 tones of agricultural produce and employed 242 days labor force per hectare. Evans et al. (2003) studied inefficiency and inequality of water allocation in an area of Ecuador. Results showed that in the downstream area, water was the main factor limiting agricultural development, but in the upstream area, land was a limiting factor. The research concluded that in water distribution law, this issue was invalided because it fails to provide efficiency and equity.

This research aimed to determine comparative advantage indexes of agricultural products by using a policy analysis matrix (PAM) in the Hamadan-Bahar Plain.

The aim was to determine an optimal cropping pattern based on market prices (maximizing private profit), an optimal cropping pattern based on shadow prices (maximizing social benefits) and, maximum amount for importation of virtual water to the province.

MATERIALS AND METHODS

Survey data

Some data in this study such as those for yield, price, costs of production for each crop and the amounts of the inputs per hectare required for crop production were collected from 63 farmers, using random sampling and in-person interviews. The following necessary information was obtained from the National Statistics Department of the Agricultural Organization and the Agriculture Organization Management and the Water Institute; cultivation area for each crop, total amounts of irrigated and non-irrigated areas under cultivation of various products and amounts of available water (ground and surface sources) in different months of the year. In addition, information and figures on the products and exchangeable production inputs, FOB, price, and formal exchange rates, Domestic price index and world price index was taken from economic reports, calendars, Central Bank of Iran (CBI), Ministry of Economy and FAO.

Firstly, products were marked that were lacking the production comparative advantage in the area using the policy analysis matrix (PAM).This was done to determine the social loss of these products as a result of cultivating them in the area, determined by calculations of the social benefits. Also was possible to identify crops with comparative advantage based on the PAM. However, the combination of activities with comparative advantage to maximize the social benefits cannot be calculated so this was done using mathematical programming models. The locale surface model marks a combination of activities to maximize the social benefits.

Mathematical programming

In this study, the cropping pattern was made originally to be put in the form of a mathematical programming problem. However, the characteristic of the production and activating factors in the pattern is meant to observe their prices or social values. In addition, the technical coefficients are determined differently from the farm's surface model. The determination of the optimal cropping pattern in the local surface is from where we can consider policy marker`s view point and not farmer`s. Maximizing social benefits due to existing constraints is one of policy markers' goals. This aim can be interpreted with the water input factor. At the farm level, due to the absence of water market development, the farmer usually uses or does not use the available water. On the other hand, for the farmer, it is not possible to save water and use it in the future, because water is a freely accessible resource; and consequently, farmers have no tendencies to save it.

The model structure at the local level is:

$$Max: \quad NSB = \sum\sum_{i=1}^{n} Y_i \left[(SP_i - SC_i) - VW_i * PW \right] * X_i$$

$$subject.to \quad \sum_{i}^{n} X_i = \overline{X}$$

$$\sum_{i}^{n} X_i \leq \overline{X_i} \qquad \forall i$$

$$\sum_{i}^{n} (Y_i * VW_i * X_i) \leq \overline{W} - Z_w \qquad \alpha_w$$

$$X_i \geq 0$$

NSB indicates net social benefits, Y_i, production yield, SP_i social value or shadow price for each unit of the products in the region, SC_i, social costs for each unit of the products except water cost in the region, Xi area under cultivation for each activity, $\overline{X}$ the total area under cultivation, $\overline{X_i}$ the maximum area under cultivation of the i th product, VW_i, the amount of virtual water that equals water requirement of i th product on the basis of cubic meters over kilograms, PW is the water price, and $\overline{W}$ is the total amount of water available in the region.

Since the amount of available water is accidental, it is considered in the model as the chance constraint, that is, chance constrained programming, suggested by Charnes and Cooper (1959).

The locale level model determines a combination of activities that maximizes social benefits. In addition, in this study, PAM is used to determine the comparative advantage of crop production in the study area.

Policy analysis matrix

For the first time, PAM was used in 1981 by American researchers to study the effects of agricultural projects and policies in Portugal (Pearson et al., 2003). PAM basically is a multiple accounting technique that presents in summary budgeting information of outside and inside farm activities (Mohanty et al., 2002). This approach is derived from the social benefit-cost and international trade theory in economics. The policy analysis matrix is a result of two accounting identities, one of them defines profitability as a difference between the incomes and costs and the other one measures deviation effect (deviation policies and market failure) as the observed parametric differences and the parameters in the conditions where there are no deviations. Profits have been defined as total revenue and production costs per unit (e.g. per hectare). The first identity of the accounting matrix is obtained by this definition. Profitability is measured horizontally along the columns in the policy analysis matrix (Table 1).

Profits, as shown in the left column, can be obtained by subtracting the costs, as specified in the mid columns, from the incomes as shown in the right first column. Each PAM consists of two cost columns, one for the tradable inputs, the other for the internal production factors. The intermediate inputs, including fertilizers, herbicides, purchased seeds, animal feed ingredients; electricity, transportation and fuel are divided by the tradable and internal factors components. This process, separation of intermediate goods and services, separated the costs of intermediate inputs into four distinct groups: tradable inputs, internal factors, transfers (taxes or subsidies used for determination of social value) and non-tradable inputs (they should be more separated so that finally all items of cost are classified as tradable inputs, internal factors and transfers).

The data entered in the first row of the matrix can be achieved by an indicator of the private or personal profitability. ‘Private’ refers to the observed income and cost, which in fact, is the market price that is received and paid by the farmers. The market price is a reflection of value and includes all the transfers and market failure.

Social prices are used in the second row of matrix. These prices measure the comparative advantage or the efficiency of the agricultural goods system. Economic efficiency is achieved in economics when the resources are used in activities that make the highest level of product and income. If the social profits are positive, this means that products have comparative advantage and in other words the resources are used efficiently (Monke and Pearson, 1989).

The third row of the matrix concerns the difference between the social and private revenues, costs and profits. Each difference between the private (market) and the estimated social prices should be explained by transfers and/ or market failure. This relationship follows directly from the definition of social prices. The social prices correct the deviations effects of policies (policies that lead to inefficient use of resources).

Based on Table 1, there were 12 variables in the PAM shown with A to L respectively. By using PAM, the following equations can be extracted (Table 2).

The first row of the matrix consists of income (A), cost of tradable inputs (B), cost of non-tradable inputs (C) and benefits (D) calculated per unit of production based on the market prices. The third row of the matrix consists of income (E), cost of tradable inputs (F), cost of non tradable inputs (G) and profits (H) calculated per the specified production quantities based on the shadow prices. In other words, the third row is the same as the items in the first row based on the calculation of the shadow prices of the product, non-tradable input and tradable input.

The net social profitability indicator (NSP)

NSP calculates the profit of the product, using the shadow prices of the products, tradable and non-tradable inputs. If NSP is larger than zero, there is comparative advantage in the production; otherwise, the production activity is lacking social profitability and comparative advantage.

The NSP calculation within the PAM framework is defined as follows.

NSP= (E-F-G)

E, is the income, G, the cost of non-tradable inputs cost and F is the cost of tradable inputs. All of them are calculated based on shadow prices. The quantities larger than zero indicate the net social profitability while the negative quantities denote unprofitability of the production.

RESULTS AND DISCUSSION

The comparative advantage

Table 3 shows the results of the comparative advantage for agricultural product in Hamedan-Bahar Plain.

Because water wheat, water barley, dry land barley, potato, water melon**,** cucumber, onion, dry land lentil, bean, tomato, water chickpea and alfalfa have positive net social index, and with internal recourses cost and social-cost benefit ratios indicators smaller than one, they have comparative advantage, but because products such as dry land wheat, water lentil and garlic have negative net social index, and with DRC and SCB ratios indicators larger than one, they lack comparative advantage.

The cropping pattern

The results for the current and optimum cropping patterns of different farming products in Hamedan-Bahar Plain for maximizing the gross margin and social profits are presented in Table 4. In the current cropping pattern, the

Table 1. Policy analysis matrix (PAM).

Calculation basis	Revenue	Inputs cost		Profit
		Non-tradable inputs	Tradable inputs	
Private (according t market prices)	A	C	B	D
Social (according to shadow prices)	E	J	F	H
Difference (policy effect)	I	K	J	L

Source: Yao (1997).

Table 2. The equations that extract from PAM.

Market benefit (private)	D = A-B-C
Policy effect on revenue	I=A-E
Social benefit (with shadow price)	H = E-F-G
Policy effect on non tradable production factors	K=C-G
Policy effect on tradable production factors	J=B-F
Net policy effect	L = D-H = I-J-K

Source: Yao (1997).

Table 3. Results of the comparative advantage.

Product	NSP	DRC	SCB
Water wheat	1111818.478	0.654	0.664
Dry land wheat	-1443656.47	1.301	1.201
Water barley	6592743.984	0.193	0.226
Dry land barley	71555449.86	0.133	0.142
Potato	23154128.81	0.230	0.334
Water melon	47813363.62	0.197	0.222
Cucumber	36396391.41	0.402	0.414
Onion	35000131.8	0.430	0.434
Water lentil	-1198755.337	1.29	1.285
Dry land lentil	191454.8416	0.920	0.924
Bean	1464959.83	0.780	0.790
Tomato	23289440.4	0.585	0.601
Water chickpea	2796235.764	0.582	0.597
Garlic	-3530749.924	1.213	1.203
Alfalfa	29812666.04	0.504	0.509

Source: Research findings.

different products under cultivation area cover 70126 hectares totally; among products irrigated wheat has the largest area under cultivation (11383 ha). The results from determining the optimum cropping pattern by maximizing the social benefits show that the area under cultivation has increased 7980 ha more than the current cucumber has increased. Also, the results for maximizing the gross margin show that the total area under cultivation has increased (8066 hectares rather than the present cropping pattern increased). In this program, pattern. In this pattern, crops such as water wheat, dry land wheat, dry land barley, water melon, onion, dry land lentil, bean, tomato, garlic and alfalfa have been removed from the program. And the crops such as water barley, water chickpea, potato, and water lentil are included in the cropping model. Additionally, cultivation of potato and some of the crops have been removed from the pattern, such as dry land wheat, dry land barley, water melon, cucumber, dry land lentil, bean, tomato, garlic, and alfalfa. But products such as water barley and water

Table 4. Results of the current cropping pattern and optimal cropping pattern with goals: Maximize the social benefits and maximize gross margin.

Product	Current cropping pattern (ha)	Optimal cropping pattern with goal maximize the social benefits (ha)	Optimal cropping pattern with goal maximize gross margin (ha)
Water wheat	11383	0	12781
Dry land wheat	10465	0	0
Water barley	0	20243	2151
Dry land barley	517	0	0
Potato	40477	42888	42888
Water Melon	1797	0	0
Cucumber	1899	4510	0
Onion	132	0	3298
Water lentil	0	639	0
Dry land lentil	779	0	0
Bean	262	0	0
Tomato	399	0	0
Water chickpea	0	9826	16984
Garlic	605	0	0
Alfalfa	1411	0	0
Total acreage (ha)	70126	78106	78192
Social benefit (million dollars)	2241	2916	2436
Gross margin (million dollars)	2153	2275	2705

Source: Research findings.

chickpea which are not cropped in the current pattern have come to the model. Furthermore, the cultivation area of products such as water wheat, potato and onion has increased.

In addition, when the model aim is to maximize social profits, results indicate an increase in the amount of social profits and the gross margin respectively (675 and 195 million dollars more than the current model). Also, when the model aim is to maximize the gross margin, social profits and gross margin (more than the current pattern) have increased respectively by 122 and 552 million dollars.

Amount of water consumption in the current cropping pattern and water requirements in an optimal cropping pattern

The amount of water consumption in the current cropping pattern and water requirements in an optimal cropping pattern for maximizing social benefits and gross margin are separately shown in Table 5. The results show the highest amount of water consumed belongs to the current cropping pattern of farming products (860.82 million cubic meters). Furthermore, second pattern shows that the highest allocation of water belongs to the program with the aim of maximizing the gross margin (840.25 m^3).

Whereas, the optimal cropping model with the maximum social benefits not only has the maximal social benefits (2916 million dollar) but also its water requirements is notably less in comparison with the other two cultures.

As shown in the results, some crops have a comparative advantage in the farming production, but when the issues of virtual water and water resources shortage are noted, the production of these crops is not allowed.

Conclusion

(1) According to the current pattern and effective production support, we can say that farming crops cultivation pattern seems to be planned based on effective production support. So, if government supports the products that have more comparative advantage, crops cultivation with comparative growth advantage and the consequently optimum utility of the sources and factors will increase.

(2) By comparing the cropping patterns, it can be inferred that the pattern with maximum social benefit not only has a highest social benefit and second gross margin, but also its water requirement is less than the two other models. So, if we promote the cultivation of this pattern, farmers and society can gain more profit; in addition,

Table 5. Results of the amount of water consumption in the current cropping pattern and water requirements in an optimal cropping pattern with goals: Maximize the social benefits and maximize gross margin.

Product	Water consumption in the present cropping pattern ( )	Water requirements in an optimal cropping pattern with goal maximize the social benefits ( )	Optimal cropping pattern, Maximize gross margin(ha) with goal maximize gross margin ( )
Water wheat	105572579	0	134049625
Dry land wheat	0	0	0
Water barley	0	23860650	3205409
Dry land barley	0	0	0
Potato	544869461	621898004	621898004
Water melon	96926350	0	0
Cucumber	48501677	123705023	0
Onion	3687081	0	30123186
Water lentil	0	2542634	0
Dry land lentil	0	0	0
Bean	16438512	0	0
Tomato	7336555	0	0
Water chickpea	0	38443689	50973776
Garlic	4326980	0	0
Alfalfa	30160805	0	0
Total acreage(ha)	70126	78106	78192
Total water consumption in the cropping pattern ( )	860820000	810450000	840250000

Source: Research findings.

shortage of water resources will be used more effectively and less than the in present situation. In fact, we can use the virtual water for this plan. In this way all members of society will have more welfare.

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