Managing cropping patterns agricultural crops of Three Counties of Mazandarn province of Iran

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ABSTRACT: Augmenting or limiting cultivation of agricultural crops in different areas shall be done with consideration of resources constraints and availability of fertile agricultural land. This makes design of multi-regional model of cultivation of crop products necessary. This model should be pervasive and integrated in one hand and separable in accordance to the region. Moreover this model shall be able to recognize the resources possessed in common between areas of region as well uncommon resources between areas. Separating a model based on area will increase model's precision for each area and superimposing these area models will results in trans-regional attitude. The result of this research shows that optimum cropping pattern will increase the total profit of regions, Babol, Babolsar, Qaemshahr, according to their show, 6.8%, 8.9%, 5.6%. Furthermore, use of multiregional model will increase the profit 8.5% to this condition and 1.4% to whole of regional models. The execution of this models result in reality is possible with optimal allocation of inputs.

Key words: Agricultural Crops, Linear Programming, Multi Regional Models, Regional Models, Optimization

INTRODUCTION

With increase in demand for agricultural products, necessity of efficient usage of scarce resources is undeniable. Optimum utilization of these resources in addition to satisfying society's demand can augment agricultural stakeholders' income (Mohammadi and Bostani, 2009). In order to utilize resources properly proper management of agricultural sector is essential, this in one hand can help farmers in the process of decision making so as to make optimum utilization of their input which is required for increased income and in the other hand will aid policy makers to achieve their short run as well as long run objectives.

One of the most important decisions in agricultural sector is determining optimum cropping pattern. The objective of determining optimum cropping pattern is to select combination of products that shall be produced in a farming unit considering characteristics of cultivation of each crop, market price forecasting, quantity of demand, available soil and water resources, labor, capital, agricultural equipment etc. in order to maximize profit earned by that farming unit (Baniasadi and Zarea Mehrjerdi, 2009).

Decision about Development or limitation of cultivation of different crops in different regions shall be made in accordance to resources limitation such as inadequacy of fertile land, this will reveal necessity of designing a comprehensive cropping pattern for agricultural crops. Separating model from regional stand point will increase precision of modeling for each region and putting together regions in a comprehensive model will provide a cross regional view. In a cross regional model one can recognize two types of resources; common resources which are those that due to mobility are transportable and allocated between different regions with minimum cost and non common resources that are those resources which are not mobile or their transport between regions is too costly (Joolaie et al., 2005). One of the basic considerations in determining cropping pattern is limitation of resources. This limitation varies in different regions with climatic, social, political and economic conditions. With abolishing these limitations agricultural profit increases and more efficient cropping pattern will emerge. One way to reduce limitations is to utilize common resources available in all regions, in this way excess resources of one region will compensate shortage of same resources in other regions in case resources can be transported between regions.

Linear programming method is widely used for estimation of optimum cropping pattern, among them we can mention Singh et al., (2001), Ishtiq Hassan et al., (2004), Chima et al., 2005, Asif Maqbool et al., 2006, Idris et al.,
2009, Saboohi and Khosravi (2009), Majidi et al., (2010). However, little work is done with application of multi-regional model. Sherbiny and Zaki (1974) used a multi-regional planning model for determination of optimum cropping pattern in Egypt. Objective of this model was to determine optimum cropping pattern based on comparative advantage. This model was developed for 17 provinces and for 25 crops which 10 of them were winter crops and rest were summer crops, as a result of implementing optimum cropping pattern that determined by this model income of agronomy increased by 22%. Joolaie et al. (2005) determined optimum cropping pattern for 3 counties of Fars province including Shiraz, Marvdasht and sepidan both in the form of separate model for each county (regional model) and in the shape of a combined multiregional model. They found that using multiregional model will increase profit by 2.03% and reduces idle land by 3% compare with all separate county models.

Mazandaran province with its fertile land is one of the most important agricultural regions of Iran. Therefore determination of optimum cropping pattern in this province is vital. Agricultural crops which considered in this research are strategic crops therefore it is required that regions which are selected for this research to be important from the stand point production of these crops. On the other hand counties which are selected to be put together to make multi regional model has to have possibility of resource exchange. As a result of these considerations three central counties of Mazandaran province including Babol, Babolsar and Ghaemshahr are selected for the aim of this research work. Objectives of this research work are as follow:

- Determination of optimum cropping pattern of agricultural crops in each county with objective of profit maximization.
- Determining optimum cropping pattern of all three counties with application of multi-regional model.
- Comparing optimum cropping pattern of counties with the optimum cropping pattern that obtained as result of solving multi regional model.

**MATERIALS AND METHODS**

In order to determine optimum cropping pattern linear programing is widely used since 1960 so this method is the oldest technic which is used in farm management (Sabohi and Khosravi, 2009). In this research work linear programming model is used for the purpose of optimization of agri products cropping pattern. To do so at the first stage for each county optimum cropping pattern with the objective of profit maximization is determined. In this stage model of each county is distinct from other counties models. The county level model can be written in the following form:

\[
\begin{align*}
    \text{MAX } Z &= \sum_{j=1}^{n} c_j x_j \\
    \text{Subject to: } & \sum_{j=1}^{n} a_{ij} x_j \leq b_i
\end{align*}
\]

In which:
- \( Z \): objective function
- \( x_j \): Decision variable of \( j \)th farm activity
- \( c_j \): function of objective function that is expected gross profit for one unit of \( j \)th farm activity
- \( a_{ij} \): technical coefficient which is amount of \( i \)th resource which is exploited by each unit of \( j \)th activity
- \( b_i \): amount \( i \)th resource which is available.
- \( n \): number of activities
- \( m \): number of limiting resources

After the estimation of regional models estimation of multi-regional model using all three regional models is necessary. Estimation of multi-regional model requires recognizing between common resources and non common resources. Study of linear programming shows that this type of structure is called Diagonal Block Matrix or Angular Block matrix System this structure first introduced by Dantzig (1963). As these type of structures contain activities and limitations which have no overlap with other limitations and activities therefore, they could be called Diagonal
Block Matrix. Structure of this model is similar to Dantzig-Wolfe decomposition algorithm. They used this decomposition algorithm to solve large models. Decomposition Algorithm decomposes models with special structure to smaller blocks and thus makes solution of this models possible (McCarl and Spreen, 1996).

A regional model can be written in following form:

\[
\begin{align*}
\text{MAX } Z &= \sum_i \sum_j C_{ij} X_{ij} \\
\text{Subject to:} & \sum_i \sum_j a_{ijk} X_{ij} \leq \sum_l b_{ik} \quad \text{for all } k \\
& \sum_j a_{ijl} X_{ij} \leq b_{il} \quad \text{for all } i \text{ and } l \\
X_{ij} & \geq 0 \quad \text{for all } i \text{ and } j
\end{align*}
\]

In which:
- \(i, j, k \text{ and } l\) are sign of block, crops, common resources and uncommon resources respectively.
- \(C_{ij}\) is coefficient of objective function for \(j\)th product and \(i\)th block.
- \(X_{ij}\) is decision variable or area under cultivation of \(j\)th crop and \(i\)th block.
- \(a_{ijk}\) : technical coefficient which is amount of \(i\)th common resource which is exploited by \(j\)th product and \(i\)th block.
- \(b_{ik}\) : is amount of \(k\)th common resources in \(i\)th block and;
- \(b_{il}\) : is amount of \(l\)th uncommon resources in \(i\)th block.

Generally, separation of blocks is due to location, time or structure of activity. First set of limitations are set of common limitations and second set of limitations are uncommon limitations of block. Objective function in this model is maximizing profit of whole model and blocks subject to common and uncommon limitations of block. Therefore, the second sets of limitations are uncommon between blocks.

Solving this type of models requires solving regional models and multi-regional model. Regional models can be solved such as any other simple linear programming models. In order to solve multi-regional model it is required to write the model in specific form. The objective function of multi-regional model is to maximize profit in all three regions. This objective function is summation of objective functions of all three regional models. In its simplest form objective function of the multiregional model can be written as follow:

\[
Z = Z_1 + Z_2 + Z_3
\]

As mentioned earlier limitations of multi-regional model are divided into common limitations and non-common limitations. Common limitations are used in case of inputs such as pesticides, chemical fertilizers, agricultural Machinery, labor and capital which their transport between counties is easily possible. Therefore, these types of limitations are protruded from regional models and form our common limitations as a results model itself take responsibility of optimum allocation of these resources and consider them as shared between regions.

Algebraic form of limitations for one input is as follows:

\[
\sum_{j=1}^n a_{ij1} X_{ij} + \sum_{j=1}^n a_{ij2} X_{ij} - \sum_{j=1}^n a_{ij3} X_{ij} \leq b_1 + b_2 + b_3
\]

Uncommon limitations are those limitations that are related to uncommon resources. Uncommon resources are resources such as land and water which are not transferable from one region to another due to low level of mobility or high cost involved their transfer between regions. Consequently, these resources are exclusive for each region. Such limitations are entered in to the model in the form of separate blocks. In our model land, labor and water are included in this category of limitations. These limitations are exactly limitations of regional models that for each region with out any mathematical relation with other regions are entered in regional model. In our model for each
region we consider 12 water limitations (in accordance to 12 months of year), 2 land limitations and 2 irrigated agriculture limitations. Mathematical relations for uncommon limitations are as follow:

\[
\sum_{i=1}^{m} a_{ij}x_{ij} \leq b_1 \quad \sum_{i=1}^{m} a_{ij}x_{ij} \leq b_2 \quad \sum_{i=1}^{m} a_{ij}x_{ij} \leq b_3
\]

After writing our problem in the shape of Linear Programming LP model to solve the model LINGO software is utilized. LINGO is one of the software that is applied to solve Linear Programming (LP) models extensively.

RESULTS AND DISCUSSION

RESULTS OF BABOL REGIONAL MODEL

Optimum cropping pattern with objective of profit maximization for Babol County which is obtained from regional model is compared with existing situation (Table 1). Table 1 shows that with applying optimum cropping pattern with objective of profit maximization that is obtained from solving Babol's regional model profit of region increases by 6.8%. With applying optimum cropping pattern obtained from solving Babol regional's model area under cultivation of canola, barley, Soya, wheat, high grade paddy and high yielding paddy decrease and area under cultivation of lettuce, dual culture of high grade paddy-clover and dual culture of high grade paddy-broad bean will increase.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Crop</th>
<th>Existing area</th>
<th>Existing profit</th>
<th>Optimum area</th>
<th>Optimum profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>High grade paddy-Clover</td>
<td>7644</td>
<td>18502882488</td>
<td>11947.27</td>
<td>28919274316</td>
</tr>
<tr>
<td>X2</td>
<td>Canola</td>
<td>981</td>
<td>572300071.9</td>
<td>868.43</td>
<td>506628492.8</td>
</tr>
<tr>
<td>X3</td>
<td>High grade paddy-Broad Bean</td>
<td>1835</td>
<td>4885459851</td>
<td>9852</td>
<td>26229727765</td>
</tr>
<tr>
<td>X4</td>
<td>Barley</td>
<td>27</td>
<td>3715110</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X5</td>
<td>Lettuce</td>
<td>812</td>
<td>680862000</td>
<td>1421.67</td>
<td>1192070295</td>
</tr>
<tr>
<td>X6</td>
<td>Soya</td>
<td>471</td>
<td>149024603.3</td>
<td>113.12</td>
<td>59991683.73</td>
</tr>
<tr>
<td>X7</td>
<td>Wheat</td>
<td>112</td>
<td>20384000</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X8</td>
<td>High grade paddy</td>
<td>29416</td>
<td>58275329863</td>
<td>21622.47</td>
<td>42835755089</td>
</tr>
<tr>
<td>X9</td>
<td>High Yielding Paddy</td>
<td>16913</td>
<td>31158593845</td>
<td>12146.58</td>
<td>22377481986</td>
</tr>
<tr>
<td>Total</td>
<td>Value of Objective Function</td>
<td>114349432473.37</td>
<td>122120929627.17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Research Findings.

RESULTS OF BABOLSAR REGIONAL MODEL

Optimum cropping pattern with objective of profit maximization for Babolsar County which is estimated by solving regional model is compared with existing situation. Table 2 shows the results of model alongside existing situation. Results shows that with application of optimum cropping pattern which obtained with the objective of profit maximization by solving Babolsar regional model profit of this county will increase by 8.9%. Comparing the optimum cropping pattern for Babolsar County with existing situation shows that area under cultivation of canola, barley, wheat and high grade paddy decreases and area under cultivation of Soya, double culture of high grade paddy-clover and high yielding paddy increases.

RESULTS OF GHAEMSHAHR REGIONAL MODEL
Optimum Cropping pattern of Ghaemshahr County with the objective of profit maximization estimated and compared with existing cropping pattern (table 3). Table 3 reveals that with application of optimum cropping pattern the county’s profit will increase by 5.6%.

Comparing the optimum cropping pattern for Ghaemshahr County with existing situation shows that area under cultivation of canola, barley, wheat and high grade paddy decreases and area under cultivation of unirrigated green beans, soybean, double culture of high grade paddy-clover and high yielding paddy will increase by application of optimum cropping pattern (table 3).

Table 2: comparing existing area under cultivation and profit with optimum area under cultivation and profit in Babolsar Regional model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Crop</th>
<th>Existing area</th>
<th>Existing profit</th>
<th>Optimum area</th>
<th>Optimum profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>High grade paddy-clover</td>
<td>1455</td>
<td>3103310127</td>
<td>6299.813</td>
<td>13436614078</td>
</tr>
<tr>
<td>X2</td>
<td>Soya</td>
<td>2071</td>
<td>2051526025</td>
<td>3089.006</td>
<td>3059959537</td>
</tr>
<tr>
<td>X3</td>
<td>Wheat</td>
<td>972</td>
<td>706978810.9</td>
<td>223.529</td>
<td>162582942.5</td>
</tr>
<tr>
<td>X4</td>
<td>Canola</td>
<td>486</td>
<td>370666125</td>
<td>300.2249</td>
<td>228977778.4</td>
</tr>
<tr>
<td>X5</td>
<td>Barley</td>
<td>99</td>
<td>35604250</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X6</td>
<td>High quality paddy</td>
<td>9036</td>
<td>14764455278</td>
<td>3362.671</td>
<td>5494467197</td>
</tr>
<tr>
<td>X7</td>
<td>High Yielding Paddy</td>
<td>5545</td>
<td>9237117654</td>
<td>6369.033</td>
<td>10609829967</td>
</tr>
<tr>
<td>Total</td>
<td>Value of Objective</td>
<td></td>
<td>30269658271.11</td>
<td>32981620000</td>
<td></td>
</tr>
</tbody>
</table>

Source: research Findings.

Table 3: comparing existing area under cultivation and profit with optimum area under cultivation and profit in Ghaemshahr County models.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Crop</th>
<th>Existing area</th>
<th>Existing profit</th>
<th>Optimum area</th>
<th>Optimum profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>Rainfed Barley</td>
<td>58</td>
<td>26988689</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>X2</td>
<td>Rainfed Wheat</td>
<td>534</td>
<td>348540161</td>
<td>35248</td>
<td>212439796.7</td>
</tr>
<tr>
<td>X3</td>
<td>Rainfed Soybean</td>
<td>1421</td>
<td>1192143213</td>
<td>1717.4</td>
<td>1440807005</td>
</tr>
<tr>
<td>X4</td>
<td>Rainfed Green Bean</td>
<td>14</td>
<td>1974000</td>
<td>66.23</td>
<td>9338430</td>
</tr>
<tr>
<td>X5</td>
<td>High Quality Paddy-Clover</td>
<td>4365</td>
<td>10581317944</td>
<td>5258.97</td>
<td>12748415494</td>
</tr>
<tr>
<td>X6</td>
<td>Rainfed Canola</td>
<td>750</td>
<td>627472031</td>
<td>667.06</td>
<td>558081990.9</td>
</tr>
<tr>
<td>X7</td>
<td>High Quality Paddy</td>
<td>7631</td>
<td>12061770912</td>
<td>4861.12</td>
<td>7683621520</td>
</tr>
<tr>
<td>X8</td>
<td>High yielding Paddy</td>
<td>4252</td>
<td>9384306851</td>
<td>6112.72</td>
<td>13490978404</td>
</tr>
<tr>
<td>Total</td>
<td>Value of Objective</td>
<td></td>
<td>34224513801</td>
<td>36143682640</td>
<td></td>
</tr>
</tbody>
</table>

Source: Research Findings.

RESULTS OF MULTI REGIONAL MODEL

In multiregional model as mentioned earlier three counties of Babol, Babolsar and Ghaemshahr are put together in one multi regional model and consume their common resources jointly. Table 4 compare results of multi regional model with total obtained from summing up of 3 regional models.

COMPARING MULTI REGIONAL MODEL WITH EXISTING SITUATION

As far as irrigated crops are concerned in multi regional model area under high quality paddy-clover and high quality paddy-broad bean increases over existing situation and area under high quality paddy and high yielding paddy decreases. The reason which multi regional model emphasis on joint cropping in addition to notable profitability of these crops is the fact that there are possibility of common usage of scarce resources in this cropping...
Joint cropping of paddy-clover is a low cost cropping system with high return and high forage value that besides increase in profit will cause augmentation in soil fertility and reduction in consumption of chemical fertilizers. In case of rainfed crops multi regional model compare to existing situation reduces area under canola, barley and wheat and increases area under green bean, lettuce and soybean, increase in the area under green bean and decrease in the area are under barley are negligible. Replacement of lettuce and soybean in place of canola and wheat is on the one hand due to higher profitability of these crops compare with canola and wheat and on the other hand is because of the fact that limitations of regional models are compensated in multi regional model and model is free in optimum allocation of resources. Figure 1 compare results of multi regional model with regional models and existing situation.
Application of regional model will increase profit by 8.5% over existing situation. The profit is also increase by 1.4% over sum of three county models. Figure 2 compare value of Objective function of multi regional model, Regional model and existing situation.

As indicated in figure 2 value of objective function increased in multi regional model compare with sum of 3 counties (3 regional models) and sum of 3 existing situation.

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