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An Organic Agriculture Model in India using Mathematical Modelling

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Abstract

Organic farming presents a solution to socio- economic, environmental and health problems caused by conventional food production methods. In this paper, we want to find how many hectares of each food type should be planted in each municipality of India so that the whole population consumes organic foods only. The model also describe the data requirements of the model and discuss data availability. Results on a small aggregate model are promising.

Key words: Organic agriculture, linear programming, mathematical modeling, agricultural planning

Introduction

Agriculture is listed as a human activity with an impact on the carbon cycle in several reports on climate change. In addition to substantially contributing to the local and global food supply organic agriculture reduces the harmful environmental effects of conventional agriculture. On a regional scale, organic farming in India presents a solution to the country's environmental, economic and social problems. In this paper, we propose a Linear Programming (LP) model to study the feasibility of organic products as the sole agricultural food source for India's population. Assuming that all and available for agriculture in India is allocated to organic farming.

Material and methods: linear programming

Since 1950s, LP has been successfully used for the modeling and solution of many real world problems. Agricultural problems are no exception in part due to the linearity requirement being naturally satisfied by most problems of agriculture. When it comes to solve problems of organic agriculture, mathematical models conducted use goal programming, dynamic LP or data envelopment analysis. These are mainly farm level studies modeling the economic conversion potential to organic farming, comparing conventional and organic farming systems, studying environmental farm planning in detail with crop rotation, land and machine availability. A country level formulation to satisfy India's food needs via organic products can be found in which is a preliminary version of the current work.

Since the goal is to enable the whole population to consume only organic foods, we assume that all arable land of India is allocated to organic agriculture. There are N different food types grown in L geographic locations. For each $i = 1\ N$, j and $k = 1\ L$, the parameters and variables are defined in Tables 1 and 2, respectively. In the model, we employ the concept of a typical family, an average household, composed of 2 adults, 2 children and 0.5 elderly persons using data on population by age group and gender .

Table 1: **Definition of model parameter as**

H_j	hectares in location *j* available for agriculture
Fj	number of typical families in location *j*
Ri	annual requirement of food i of one typical family (kgs)
Yij	yield of food i in location j under organic farming (kgs/hectare)
djk	distance between locations j and k (km)
SC_{ij}	cost of shortage of food type *i* in location *j*

Table 2: **Definition of model variables**

xij	hectares to be allocated for growing food type *i* in location *j*
tijk	kgs of food *i* shipped from location *j* to location *k*
rij	kgs of food type *i* produced in location *j* for consumption in the same location
eij	excess kgs of food type *i* in location *j*
sij	kgs of food type *i* in shortage in location *j*
iij	kgs of food type *i* inventoried in location *j*

The problem is then defined as:

$$\text{Minimize } z = \sum_{i=1}^{N} \sum_{j=1}^{L} \sum_{k=1}^{L} d_{jk}\, t_{ijk} + \sum_{i=1}^{N} \sum_{j=1}^{L} SC_{ij}\, s_{ij}$$

Subject to

$$Y_{ij}\, x_{ij} = r_{ij} + \sum_{k=1}^{L} t_{ijk} + i_{ij} \qquad \text{for } i=1 \;\; N \text{ and } j=1 \;\; L \quad \textbf{(1)}$$

$$r_{ij} + \sum_{k=1}^{L} t_{ikj} + s_{ij} - e_{ij} = F_j R_i \qquad \text{for } i=1 \;\; N \text{ and } j=1 \;\; L \quad \textbf{(2)}$$

$$\sum_{i=1}^{N} x_{ij} \le H_j \qquad \text{for } j=1 \;\; L \quad \textbf{(3)}$$

$$t_{ijk}, r_{ij}, x_{ij}, e_{ij}, s_{ij} \ge 0 \qquad \text{for } i=1 \;\; N \text{ and } j=1 \;\; L$$

The objective is to minimize **z**, the total distance travelled by food and total amount of food shortage representing the cost of not satisfying food needs from local produce or not satisfying at all. Constraints (1) impose that the amount of each food type produced in each region is either consumed or inventoried in the same region or shipped to other regions. Constraints (2) ensure that the food needs of the population are met and keep an account of any food shortages whereas (3) represent the land availability constraints.

Data requirements and sources

The LP model proposed above had various data requirements. First of all, the different food types to be included in the model should be selected; eventually we plan to include all foods consumed regularly by the population. There are two options for selecting the different geographic regions to be considered municipalities or agricultural basins. For both choices as regions, some data is available either from the ministry of Food, Agriculture and Livestock or from the India Statistical Institute. To account for the whole population we estimated the number of typical families in the country to be 15 million distributed appropriately to different geographic regions. Data needed is summarized in Table 1 as the amount of arable land in each region, the number of people living in each region aggregated to typical families, yearly food requirements of typical families, yields of each food in each region under organic farming conditions, distances between regions and costs of not satisfying a food requirement in a given region. Among those data requirements, yield information is the most difficult one to obtain. Next, we describe the different data sources to be used.

Arable land:

Eventually, we plan to run the model with municipalities as locations; data on available arable land in each municipality is available. An alternative is to use agricultural basins made up of several municipalities. Agricultural basin model is used by the Ministry on the basis of similarity in terms of climate, production efficiency and soil quality.

Geographic distribution of the population:

Population by provinces data is available . Some pre-processing of data needs to be done to obtain the population of each municipality.

Annual food requirement of a typical family:

We determine an average consumption level for a typical family for each food type using purchasing patterns of organic food consumers. This information is obtained through interviews at the organic marketplaces in Istanbul. This is in contrast to the model proposed in Demir (2007) which uses nutrient requirements. Still, we plan to ensure that these average consumption levels satisfy general nutrient requirements.

Organic yields:

Data on yields will be found through certification agencies and discussions with organic farmers serving organic markets in different cities of India.

Shortage costs:

Shortage costs are used to understand whether India can produce a sufficient amount of organic foods to feed its population properly. We will update these costs until a balance between the amount of shortages and the amount of food transported is reached

Conclusion

Projections indicate that climate change will impact food security in India propose a mathematical model to come up with an organic agriculture plan for India. We also discuss data requirements of the model and potential sources from which these data can be obtained. It has been acknowledged that data collection is a difficult phase of our study. Results on a small instance of the problem are encouraging. Eventually, we plan to obtain results that incorporate the majority of the foods consumed and all the municipalities in India with more realistic organic yield data.

Suggestions to tackle future challenges

To reduce the negative impact of human activity on climate change and the adverse health, environmental and social problems caused by conventional agriculture, conversion to organic agriculture is necessary globally.

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