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LAND, WATER, POLLUTION AND PRODUCTION IN AGRICULTURAL DEVELOPMENT: THE CASE OF "GAP"

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ABSTRACT

In this research, the potential problems of a regional development project (Southeastern Anatolian Project - GAP) related to land use, land degradation, water resources, agricultural pollution and production are analyzed in systems perspective. For this purpose, the dynamic simulation model GAPSIM is developed. GAPSIM simulates the development rate of irrigation schemes, hydropower production with respect to irrigation releases, water availability on farmlands, crop selection and production, salinization, pesticide and fertilizer consumption, rangeland and forest quality and urbanization and population dynamics in GAP during 1990-2030.

The reference behavior of GAPSIM points to many problems. According to the model reference run, increased intensity of the most evapotranspirant crop cotton on fields causes significant water scarcity, which hinders development rate of irrigation into new acres. Also, water diversions to farmlands decrease and inhibit crop growth. On the other hand, increased monoculture cultivation of cotton leads to increased pest density on farmlands. Pesticide application rates gradually increase in order to sustain yields.

Two factors have considerable effect on water availability, arable land use, agricultural pollution and agricultural production. Both of these scenario analyses related to "attitudes in crop preference" and "rate of land transformation" imply democratization of irrigation through improved infrastructure and farm extension practices. First, a significant improvement in system performance is achieved if those attitudes in crop preference which create bias towards monoculture cultivation of traditional crops are altered and rotations of new crops are stimulated. Secondly, if all farmers are assumed willing to transform their rainfed farm systems whenever water is available, more lands are irrigated and the cropping intensity of the most evapotranspirant crop cotton is hindered as water delivery per individual farm is decreased.

In the following sections of this paper, a short model description accompanying the MS PowerPoint presentation and references are prowided. A more detailed policy analysis with GAPSIM is available at Saysel et al. (1999).

MODEL DESCRIPTION

GAPSIM simulates the development rate of irrigation projects, hydropower production, water availability on farmlands, crop selection and production, salinization, pesticide and fertilizer consumption rates, soil erosion, rangeland and forest quality, urbanization and population

dynamics in GAP during 1990-2030 period, which comprises water facilities construction process.
GAPSIM computer model consists of about two thousand variables and fourteen sectors representing different environmental and economic components of the GAP system. The model is developed on *STELLA Research* software (HPS, 1996) designed for dynamic modeling of complex systems. For full model diagram and equations, complete information is available in Saysel (1999).
In the model overview GAPSIM model sectors and their basic interactions are represented. Possible *land flows* in GAPSIM are represented with "bold" arrows. These are from rangelands and forestlands to rainfed fields; from rainfed fields to urban lands; from rainfed fields to irrigated fields and in-between fields and wine-garden. "Thin" arrows information exchange between sectors. *Rainfed fields*, *irrigated fields* and *wine-garden* sectors constitute the "arable lands group" and for clarity of presentation, they are treated as a single object in the diagram.

Arable Lands Sectors

Arable lands in GAPSIM are central to the model, so that they have interactions with all other sectors except the *government sector*. Three sectors constituting arable lands, *rainfed fields*, *irrigated fields* and *wine-garden* supply agricultural products to the *market sector* and receive information from this sector about prices of these products. They provide information on current crop patterns and input requirements to *fertilizers, pesticides*, *irrigation-salinization* and *erosion sectors* and receive information about fertilizers and pesticides consumption rates and salinization and erosion effects on yields from these sectors respectively. Arable lands deliver the fodder potential of lands and profitability of non fodder field crops to *livestock and rangelands sector* and receive the population of sheep fed on farmlands from this sector. They receive information of rural population from *population sector* and supply food to this sector. Finally, arable lands in GAPSIM receive information about irrigation development rate from *water resources sector*.
For each arable land sector, several farm systems are identified, each representing a different possible crop pattern in GAP. For rainfed fields, CERF (CEreals monoculture Rainfed Fields) and CEPRF (CEreals-Pulses rotation Rainfed Fields) and for irrigated fields, COIF (COtton monoculture Irrigated Fields), COSIF (COtton-Summer crops rotation Irrigated Fields), CESIF (CEreals-Summer crops rotation Irrigated Fields) and CCSPIF (Cotton-Cereals-Summer crops-Pulses rotation Irrigated Fields) are distinguished. Wine-garden is classified as RFWG (RainFed Wine-Garden) and IRWG (Irrigated Wine-Garden). On arable lands, seven major commodities are produced, namely, cereals, pulses, cotton, oil crops, summer cereals, vegetables and fruits, each one aggregating a set of agricultural products in GAP. In the model, oil crops, summer cereals and vegetables are grouped under the category of *summer crops*. Each farm system generates its own yields, income, production factors and costs for calculation of profitability associated with that farm system. These calculations are based on primary farm products and primary production factors such as fertilizers, pesticides, seeds, fuel, irrigation and labor. The land flows between different farm systems are modeled by flow variables where the rates are calculated according to two basic criteria: relative profitability of different farm systems; and the effect of traditional attitudes which creates bias towards those crops safe in marketing (i.e can be stored under low cost), widely produced in the region and requiring low know - how.
The transition from rainfed fields to irrigated fields is modeled through flow variables representing development of irrigation in GAP whose values are obtained from *water resources sector*. Also, there exists land flows from rangelands and forests to rainfed fields and from rainfed fields to urban lands.

Irrigation and Salinization Sector

Irrigation and salinization model in GAPSIM represents quantity of irrigation water applied on irrigated lands, portion of this water evapotranspirated which leaves salt on soil root zone and portion infiltrated through root zone which flushes the salt in soil root zone and recharges groundwater (Johnson and Lewis, 1995). Then, an average salinization profile and its effect on yields of different crops for GAP irrigated arable lands are calculated. The salinization model is discussed in detail in Saysel and Barlas (1999).

Water Resources Sector

GAPSIM water resources sector describes aggregate water releases for hydropower production under different construction and operational constraints with respect to changing irrigation water demand generated by arable land sectors. Water resources sector informs *arable lands* on irrigation development rate. It supplies irrigation water to *irrigation and salinization sector* and receives water demand information form this sector. It also receives input about summer crops availability from *market sector*. Finally it receives information about probable delays in GAP construction from *government sector*.

Fertilizers Sector

Fertilizers sector in GAPSIM represents changing fertilizer application rates in different fields and amount of mineral nitrogen that will be leached from each field. While calculating the fertilizer quantities, it is assumed that the initial quantities are the proposed minimum rates in TOBB, 1994 and in GAP-RDA, 1990 and can be increased by the farmers as a reaction to decreasing yields in the long term in order to sustain conventional yields. Increasing use of artificial fertilizers still, is the major and simplest practice in enhancing farm yields in transient technology agricultural systems, masking adverse effects of soil erosion on fertility (Mannion, 1995). Therefore, decreasing soil fertility because of land degradation processes may be compensated with increasing application of chemical fertilizers (Pimentel et al., 1993).

Pesticides Sector

GAPSIM pesticides sector represents annual pesticide application rates in order to sustain conventional yields for each field and wine-garden stock with respect to changing residence time of monocultural practices and pest resistance development. Major pesticides in the market belong to the groups such as organochlorines, organophosphates, synthetic pyretroids, carbamates, phenoxy compounds, benzimidozols, triazols and etc., all different by their persistencies and toxic effects in the environment, but, similar by their short term effect on reduction of pests and long term effect on pest resistance building. These chemicals are grouped under a broad category as "pesticides" in terms of effective material in statistics concerning aggregate pesticides consumption and aggregate yields. According to global data, crop losses to pests increase despite intensified pesticide use, and among several reasons, the increase in pests that are resistant to pesticides, the reduction in crop rotations and the increase in monocultures and reduced crop diversity play major role in increasing losses (Pimentel, 1991). Resistance is exacerbated by insecticide overuse and acts as a stimulant for the pesticide industry (Mannion, 1995). Since resistance is developed gradually, as the effect of pesticide decreases, farmers tend to increase pesticide application rates (Delen et al., 1995). In the model, initial pesticide quantities are taken from GAP-RDA (1988). A detailed discussion for model structure is available in Saysel 1999.

Livestock and Rangelands Sector
Rangelands and livestock sector represents livestock load and its effect on rangeland destruction under changing herd sizes and rangeland qualities. Livestock and rangelands sector supplies agricultural products to the *market sector* and receives their price information from this sector. It receives population density information from *population sector*. It gives range quality information to *erosion sector* and receives information on erosion effect on rangeland regeneration rates. Finally it receives rangeland costs and rangeland improvement information from *government sector*.

Forests Sector
Forest sector represents changing forest lands and forest quality. It receives timber requirement from *urban sector*. It also receives information on population density and on firewood requirement from population sector. Finally, it receives forest planting information from government sector. Forests sector gives forest quality information to erosion sector and receives erosion effect on forests regeneration rates from this sector.

Erosion Sector
GAPSIM erosion sector describes loss in soil depth on arable lands, rangelands and forests according to the formulation suggested by universal soil loss equation (Schwab et al., 1993) and parameters provided for GAP region. Then, it calculates the effect of soil erosion on farm yields and rangelands and forests regeneration. Together with the eroded soil, plant nutrients and organic matter are also lost which results in a decline in the productivity of soils (Hudson, 1971).

Urban Sector
GAPSIM urban sector is an aggregation of all urban sites in GAP taken as a system of interacting industries, housing and urban population (Alfeld and Graham, 1976). Each industry structure creates its own products for consumption of either other industry structures or population and creates demand for other industry products. Urban sector informs market sector about demand for agricultural products and receives information of demand for agricultural production factors. It also delivers water and energy requirements to the water resources sector. This sector receives urban population from population sector and gives information on job availability to this sector. Finally it receives desired public jobs from government sector.

Population Sector
GAPSIM population sector models the size of population living in subsettlements and villages (rural population) and size of population living in towns and cities (urban population) with respect to specific net birth, emigration and immigration rates determined under urban employment and rural subsistence level (food availability) constraints.

Market Sector
GAPSIM market sector is an aggregation of agricultural markets in GAP region where prices of major commodities are determined with respect to availability criteria based on total supply and total demand.

Government Sector
The interactions of government sector with livestock and rangelands, forests, urban and water resources sectors are already described. Apart from these, government sector intervenes the

market by delivering governmental purchase percentages for individual agricultural product to this sector.

Finally, GAPSIM receives external demand for agricultural products (in the market sector), for agricultural processed products (in its urban sector) and for hydropower (in water resources sector). Also, it receives information on employment rate outside the region (in population sector).

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