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A regional model for integrated water management in twinned river basins

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D 27, Tested socio-economic model in the Chirchik basin

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PU	Public	x
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to group specified by the consortium (including Commission Services)	
CO	Confidential, only for members of the consortium (including Commission Services)	

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INTRODUCTION

1.1 Background

This work was undertaken within the framework of the project ***(RIVERTWIN) - "A regional model for integrated water management in twinned river basins"***, beginning - 2004, end - 2006.

1.2 Objective

Developing Socio-economic block for the **Chirchik-Akhangaran-Keles** basin. Determining composition of models and their interaction order within the general set of blocks contributing to operation of the **Integrated regional model**.

1.3 Research object

The research object is the **Integrated regional model of the Chirchik-Akhangaran-Keles** basin.

1.4 Status of research

For the **Chirchik-Akhangaran-Keles** basin, ASBmm model version was proposed as a socio-economic block, with the following hierarchical structure:

- Basin,
- Districts (rayons), cities.

This block is comprised of a set of models that represent the agricultural productivity (EPIC, SOTER), the regional agricultural economy (SLISYS, GAMS), the regional water demand (WEAP) and the block of ASBmm models simulating demography and income dynamics of various social groups. Besides simulation calculations, operation of the models in the socio-economic block includes optimization components reflecting management processes in agriculture and water distribution. Based on long-term SIC's research, the most probable three macroeconomic development scenarios of the Aral Sea basin were selected. Those are referred to as "Optimistic scenario", "Business as usual", and "National Vision" scenario. Each scenario is characterized by a set of aggregated indicators that show dynamics of various physical, social, and economic elements contributing to regional development. By using the aggregated indicators of the above-mentioned scenarios and the State long-term regional development plans, we elaborated more detailed scenarios of future water-related and agricultural development in ChAKB, where probable future climate changes, specificities of the three rivers (Chirchik, Akhangaran, and Keles) and characteristics of given land area are taken into account. The main objective of the Socio-economic block is assessing impact of various regional development scenarios on socio-economic indicators of population and agricultural production. Therefore, at first stage, the ASBmm models were analyzed for correspondence between their capacities and the requirements of the RiverTwin project.

The socio-economic block of ASBmm [1] considers two hierarchical levels – water-management basin and district – that are interlinked through water and economy. The hierarchical level "basin" represents the whole industrial sector, while "district" relates to population and agricultural production. From point of water-management basin, individual rayon is viewed as a concentrated object consuming a certain quantity of water and investments, with further internal re-distribution of the latter in space and time and accompanying changes in water quality. The district response is the agricultural output per crop and the wastes discharged through collector-drainage network. Income and profitability level in each district are calculated from the current cost of agricultural output and the established resource prices. The industrial sector is given in form of trends estimated from historical series and the State regional development plans. In its developed version, the block of models ASBmm rests on historical time series of regional economic parameters such as per capita income, national income, etc. Any future economic decisions are assessed, based on historical dynamics of these parameters. Such approach is not always reasonable since the historical time series were not obtained from experiment but from statistical estimations, where values of macroeconomic parameters could be distorted due to the so called "noise" of random disturbances not linked with specific economic decisions. Hence, the assessment of future economic decisions based on such information may be doubtful. In the version of Socio-economic block for the RiverTwin project, the model was extended to carefully consider current physical and economic regularities. Besides, we improved a method for describing system status by using parameter distribution functions. Here we followed three principles formulated by D.Forrester 35 years ago in the preface to "Global dynamics": "… First, the best existing model should be identified for any moment of time; second, the best modern model should replace less clear and less accurate conventional models. Third, active efforts should be taken for regular modernization of available models… [2]». As earlier, part of information is used for visualization through GIS system.

1.5 Goals and objectives of water sector in the regional socio-economic development

The water sector plays an important role in arid zone in general and, particularly, in the Chirchik-Akhangaran basin and practically makes for a possibility of further development. Water supply contributes in different ways to any field of human or economic activities. Thus, in light of decisions made at Johannesburg Summit 2002, the objectives in water sector would be set from the point of how they are contributing to achievement of Millennium Development Goals. In terms of socio-economic development, which would be reflected in modeling set SEM these objectives are as follows:

- № 1 – no people living below the poverty line;
- № 2 – no hunger and ensure opportunities to increase calorie consumption up to required standard;
- № 4 – improve health and reduce morbidity (in particular, water-borne diseases);
- № 10 – access of population to safe water and sanitation;
- № 11 – environmental well-being and social usability of good clean environment to the benefit of humans (aquacultures, fishery, recreation, etc.)

The goal functions of water and the objectives of water sector are different in socio-economic development both proceeding from goals common for all mankind and based on functional characteristics of the sector. From this viewpoint, the following links between the water sector and other economic sectors would be clearly seen in general economy and social development:

- <u>contributor to sustainable economic progress</u>, where water is not a main factor of production but rather irrevocable (for instance, steel, rubber and chemistry production) or technological elements (coolers, slag disposal in chemical plants). Here water consumptively used in quite minor share (2…5 %) guarantees high-tech production processes, mainly, in industry, this contributing to GDP, employment, development of industries and social welfare of associated workers;
- <u>determinant of municipal economy</u>, where quality of water and access to water for each human according to his/her right, rather than quantity of water for direct use, serve as a guarantee of social (hygienic, domestic, cooking, recreation) comfort through water supply to user and sanitation;
- <u>major role in production of irrigated agriculture</u>, fishery, as a main factor of production volume (as well as in electric energy generation;
- <u>associated role in volume of agro-industry</u> and services that depend on quantity of irrigated agriculture production.

Based on the above-mentioned and the analysis of how water use impact economic and environmental indicators in the basin, as described in the report D-25, the socio-economic model would cover the following fields of economic development:

1. Industry not associated with agricultural production. Proceeding from trends and considering potential additional capital investments, we will compute volume of gross product; GDP (as a sum of income and salaries); needed water quantity, which has priority over other uses; electricity needs; employment; size of capital investments generated in the sector itself through developing production and accumulation funds;
2. Municipal economy. Modeling of the sector is based on scenario of demographic development, including total (urban and rural) population growth; provision of population with water, sanitation, electric energy; current state of wastewater treatment; required investments for management to ensure adequate living conditions. The output is needed quantity of water per year for public utilities and relevant investments to be made from own sources.
3. Agricultural sector. The agricultural production is calculated by models described in the agricultural block (section 5). Here, the outputs are to be:
   - volume of agricultural output per product and cost indicator;
   - net production (equivalent to GDP);
   - required quantity of water in time;
   - employment;
   - size of needed investments and possibility to mobilize own funds;
   - water conservation costs;
   - food supply balance.

   In this model, water availability has clear effect of on all these indicators and this fact would be incorporated by the hydrological model of the sub-basin. In addition to direct effect from various types of agricultural production, by using selected research results described in the report D-25, section 3.1 (Stulina G.V.), we take into account income generated in homestead plots in rural area (K = 0,36 to average income of agriculturists).
4. Agro-industry. The model is derivative of the volume of agricultural production and the needed investments, the output of which, as in previous, is all derivations, except for the last two.
5. Services sector is determined on the basis of trend data, from the ratio of services GDP to total GDP excluding services. In this variant, the services inputs include volumes of transport, construction, trade, and procurement. The outputs are: volume of water use, electricity, employment, required investments.

   Thus, the general socio-economic model gives major indicators of production, GDP, employment, GDP per capita, water use, investments, food basket provision through own sources, provision with water, sanitation, and electricity. The important elements are balances of investments, water and natural resources.

2 DESCRIPTION OF SOCIO-ECONOMIC BLOCK

As a basic variant of the Socio-economic block, we use the already developed version of ASBmm [1], which considers two hierarchical levels, “province”, “district”, where population is divided into urban and rural, and the main macroeconomic parameter indicating living conditions in the region is gross domestic product, GDP. GDP of province is an additive result of various production activities, which is generated as a certain share (different for various production sectors) of their gross product. In the proposed variant of Socio-economic block, whole activity in the region is divided into the following components:

I – non-agricultural product processing industry,

II – agricultural product processing industry,

III – service sectors, including municipal economy,

IV – agricultural production sectors,

Involvement of urban and rural population in production activities is as follows:

Urban population – first three sectors,

Rural population – last three sectors.

Spatial associating of activities per hierarchical level:

Province - {I, II} – province as a whole, with selection of concentrated zones of large urban industrial mergers.

District - {III, IV} – agricultural production – associated with design and actual district indicators; - services sector may be specified in 2 options: either directly proportional to volume and distribution of other sectors or proportional to distribution of population.

Government and international investments are identified per sector if related to first three groups or per district in case of agricultural production sector. Besides these investments, other sources are used in form of own accumulation funds or depreciation charges. District management is performed through water volumes and investments directed to agriculture against a background of GDP by other economic sectors.

In turn, each activity is characterized by its own set of variables and functions reflecting its spatial, technological and biological features.

2.1 Non-agricultural product processing industry

This industry is considered in the province in general and as a component and separate zones of industrial aggregation – Chirchik, Angren, Akhangaran, Gulistan, Yangiyul… contributing to GDP generation. This sector uses a certain quantity of water, further generating wastewater, and is characterized by:

- producing capacity of GP (gross product),
- water supply norm,
- depth and quality of wastewater,
- number of job places,
- GDP as a share of GP ,
- function of GP development, according to scenario and investments.

Power industry is considered in association with water intake points and as a component generating electric energy. It contributes to GDP. The industry consumes certain quantity of water which equals wastewater generated in this sector and is characterized by:

- producing capacity,
- water supply norm,
- changed temperature of wastewater,
- function of producing capacity development, according to scenario and investments.

2.2 Agricultural product processing industry

Agro-industry is considered in association with province and as a component contributing to GDP. This sector uses a certain quantity of water, further generating wastewater, and is characterized by:

- producing capacity of GP,
- water supply norm,
- agricultural output supply norm,
- depth and quality of wastewater,
- number of job places,
- GDP as a share of GP,
- function of GP development, according to scenario and investments,

2.3 Services sector

Services sector is considered in association with province and as a component contributing to GDP. This sector uses a certain quantity of water, further generating wastewater, and is characterized by:

- population (urban and rural),
- number of able-bodied citizens (urban and rural),
- norm of water supplied per person,
- electricity use norm,
- food consumption norm (consumer goods basket),
- cost of consumer goods basket,
- cost of public utilities (area + water + electric energy),
- mean income per person,
- depth and quality of wastewater.
- producing capacity of GP, as shares (I + II + IV),
- number of job places,
- GDP as a share of GP.

Population dynamics is simulated by urban and rural population according to trends and accepted scenario. Value of income is determined through province's GDP for I and II sectoral groups and incomes generated by services sector and agriculture by districts.

3 DESCRIPTION OF AGRICULTURAL SECTOR

Agriculture is comprised of three major components:

- Production of agricultural machinery, farm implements and mechanisms, their after-sales service; production of mineral fertilizers, chemical plant protection, etc.
- Agricultural production itself (farming, livestock breeding and poultry farming, fishery, etc.),
- Processing of outputs from crop production, livestock breeding, poultry farming, fishery, silkworm breeding.

The agricultural block only considers the agricultural production itself, functioning of which is described by the Planning zone model, with some extension to consider dry-land farming, livestock breeding and fishery. Each district is viewed as non-overlapping set of the following areas:

- Irrigated areas,
- Dry lands,
- Pastures and meadows,
- Ponds and fish hatcheries,
- Homestead land
- Forestland.

Agricultural production evolves in these areas and generates a food package for consumer goods basket, the forage reserve and the technical crop supplies.

Crop production:
- in irrigated area,
- in dry land,
- in homestead land.

Livestock breeding:
- cattle,
- small ruminants,
- poultry,

Fishery:
- in ponds and fish hatcheries.

Each line is linked with a certain space and generates wastes discharged into collector-drainage network.

3.1 Crop production

3.1.1 Irrigated area

This is a part of district area, which is used for crop production and has irrigation system. The irrigated area may have several outlets from irrigation systems. The irrigated area is characterized by soil, cropping pattern, and crop parameters (collector-drainage systems are not considered in given project).

Irrigated lands

These are lands used for crop cultivation and characterized by:
- soil,
- efficiency, which is a general indicator reflecting the irrigation technique applied (the so called efficiency of irrigation technique, which depends on various factors, such as field length and slope, soil permeability, etc. and is taken as average for the whole district).
- cropping pattern – a share of the total irrigated land area under a certain crop. In modeling, the cropping pattern may change as a result of re-specialization and due to expansion or reduction of the total irrigated land area.

Irrigation system

It is a system delivering water in required quantities and in specific time intervals. The irrigation system is characterized by maximum capacity and efficiency (at present, the maximum capacity of irrigation systems usually is enough for irrigation needs, therefore in modeling dynamics of irrigation systems, only efficiency of the system is considered, which is averaged for the district).

Soil

It is an element, which gives basic conditions for crop growing and is characterized by water and physical features and availability of:
- humus,
- nitrogen,
- phosphorus,
- potassium.

3.1.2 Dry land

This is a part of district territory, which contributes to agricultural production through dry-land farming. In contrast to irrigated area, it is characterized only by:
- soil yield class;
- cropping pattern and crop parameters.

3.1.3 Crop

According to theoretical data of I.S.Shatilov, A.F.Chudnovskiy [2] and V.A.Dukhovny, S.A.Nerozin [3], the model considers the following major levels of land productivity:

$$MVY \Rightarrow PY \Rightarrow DVY \Rightarrow YH \Rightarrow RY$$

- MVY is the highest possible yield, which is determined by genetic parameters of a crop variety under ideal growing conditions.
- PY is the potential yield, where zonal climatic conditions and long-term soil fertility indicators are taken into account.
- DVY is really possible yield, which gives an assessment of the highest possible crop yields under specific soil conditions and given climatic year.
- YH is the farm yield, which includes estimation of possible yield in the farm, which is affected by actual conditions of plant development phases in given year, under standard application of mineral fertilizers and standard irrigation regime.
- RY is actual yield formed by actual water stresses, technological and managerial interventions, financial inputs and other deviations from standards.

The levels of land productivity mentioned above include specific factors that influence crop yields. The quantity of generated agricultural output may be regulated through control actions.

Crop productivity levels [t/ha] in Tashkent province

Table 3.1

Crop	PY	DVY	YH	RY
Raw cotton	5.8	4.5	3.6	2.3
Cereals	8.8	6.8	5.0	3.9
Corn	11.0	8.6	7.0	3.5
Rice	9.3	7.2	5.9	3.9
Potato	42.0	33.7	25.2	18.6
Vegetables	39.0	32.4	26.3	21.9
Cucurbits	45.7	35.4	27.5	16.7
Fruits	31.5	20.8	11.7	4.7
Grapes	34.5	23.0	12.3	5.5
Forage roots	53.0	42.5	35.0	28.9
Kenaf	34.0	27.0	22.5	15.5
Perennial grass of past years (hay)	26.5	21.8	16.3	10.4
Perennial grass of past years (green forage)	60.0	52.5	39.1	27.3
Maize (silage and green forage)	58.0	45.3	34.8	24.3
Perennial grass of current year (green forage)	42.0	35.5	27.9	17.5
Perennial grass of current year (hay)	13.8	10.9	8.8	5.5
Annual grass	31.7	26.0	20.4	13.0

Besides the above mentioned yield levels, each crop produced in given irrigation contour is characterized by the following parameters:

- total cropped area,
- current unit product cost,

Furthermore, each crop is characterized by the following set of functions reflecting yield variations:

- productivity growth function of unit crop production costs (depends on actual economic level of agricultural production),
- stress function of fertilizer impact,
- stress function of water shortage.

3.2 Livestock breeding

cattle,

Quantity of cattle bred in given district; contributes to the consumer goods basket through meet and milk and by-products; has the following characteristics:

- quantity,
- mean unit weight,
- mean milk productivity,
- breeding rate,
- slaughtering rate,
- feeding rate (in fodder units),
- weight increase function depending on quantity of fodder units,
- milk productivity increase function depending on quantity of fodder units,
- coefficient of wastes (out of actual feed volume) contributing to manure formation.

The fodder units are generated by cropped areas (irrigated and dry land) and pastures and meadows.

small ruminants,

Quantity of small ruminants bred in given district. Small ruminant breeding contributes to the consumer goods basket through meet and is characterized by:

- quantity,
- mean unit weight,
- breeding rate,
- slaughtering rate,
- feeding rate (in fodder units),
- mass increase function depending on quantity of fodder units,
- coefficient of wastes (out of actual feed volume) contributing to manure formation.

The fodder units are generated by cropped areas (irrigated and dry land) and pastures and meadows.

poultry,

Quantity of poultry bred in given district. Poultry farming contributes to the consumer goods basket through meet and eggs and is characterized by:

- quantity,
- mean unit weight,
- breeding rate,
- killing rate,
- feeding rate (in fodder units),
- mean productivity of egg production,
- mass increase function depending on quantity of fodder units,
- coefficient of wastes (out of actual feed volume) contributing to manure formation.

The fodder units are generated by cropped areas (irrigated and dry land).

3.3 Fishery

Ponds for fish-farming

A part of district territory contributing to the consumer goods basket through fish production. It is characterized by:

- area of ponds,
- unit quantity of fish specimen per 1 ha of water surface,
- mean unit weight,
- breeding rate,
- catch rate,
- feeding rate (in fodder units),
- norm quantity of required water.

Fish in rivers

Quantity of fishes that inhabit the neighboring rivers. At present, river fish does not contribute to the consumer goods basket in Tashkent province; therefore, the quantity of fish in the rivers is considered only as an indicator of good environmental conditions in river itself.

4 FORMALIZATION OF SOCIO-ECONOMIC BLOCK

4.1 Management structure

For formal description of basin socio-economic functioning and development in each State, we selected traditionally established three hierarchical levels, Figure 4.1:

- center,
  - districts,
    - cities,
    - rural area.

Figure 4.1 shows fan-shaped hierarchical chart, which means that in the process of formalization of socio-economic relationships, the Center may intervene in any city or rural area only via respective district; however, interaction is allowed of any entities (cities and rural area) that are under jurisdiction of one district.

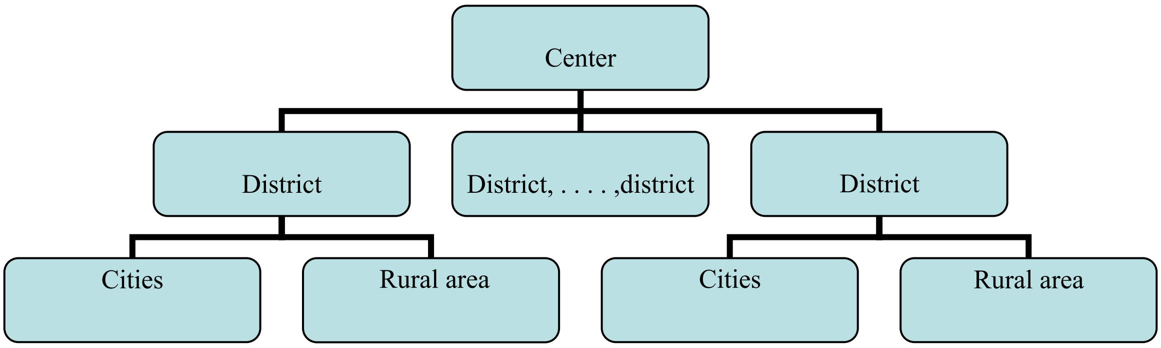

Figure 4.1

The causes of establishing hierarchical structures in socio-economic system management, in essence, are almost the same as in engineering systems – that are impossibility of centralized information processing in time intervals needed for making adequate decisions. However, unlike engineering systems, the decentralization of management in socio-economic systems gives rise to a number of exclusively man-caused problems; usually, those problems are related with a concept of homeostasis inherent in biological systems. Once a share of decision making authority is delegated from the upper hierarchical level to separate branches, each branch (in our case - district) gets certain abilities to achieve its own, intrinsic goals. Those goals, as a rule, do not correspond to general Center's goals. This leads to contradictions that are particularly acute in distributing resources allocated by the Center. If follows that management in socio-economic systems is different from that in engineering ones, and, consequently, modeling of functioning and development of the former systems demands for consideration of those objective specificities.

4.2 Description of variables

For formal description of relationships and location of entities in given system, we will introduce a set {j} = {Taskent, Akkurgan, Akhangaran, . . . Yangiul}, which corresponds to the set of districts in the province + Tashkent city, which is treated as a management center. We will denote the current time by "t". The proposed model uses variables of the four main types:

- state variables, dynamics of which is monitored from year to year, i.e.

  $\boldsymbol{X}(t) = \boldsymbol{X}(t\text{-}1) + \delta\boldsymbol{X}(t);$

- flows formed in given year "t", depending on state and control variables,

  $\boldsymbol{f}^{X}_{j,k}(\boldsymbol{X},\boldsymbol{U}),$ positive flow direction is "j" ⇒ "k",

- control variables determining current flows,

$\boldsymbol{U^X}$, $\boldsymbol{U^X(t)}$,

- indicators reflecting dynamics of any variable by spatial or temporal factor. The indicators may or may not be included in the equations for ***U*** and ***f*** .

$\boldsymbol{p^X}(t)$,

In turn, all the variables are divided into “external” or “internal”, depending on their relationship with the Model:

- external (exogenous) variables are formed as time series determined by different (climate, economic, social) scenarios,
- internal (endogenous) variables are formed within the context of the model through computation by any equation.

State variables:

Population:

$N_j(t)$ is the total number of people in district “j”, some people living in cities and others in rural area [thousand], then

$N_j^{urban}(t)$ and $N_j^{rural}(t)$ are urban and rural social groups, respectively, in district “j”.

$N_j(t) = N_j^{urban}(t) + N_j^{rural}(t)$;

In our model, these groups are the smallest socio-economic units, for which resources will be allocated and their goals will be formulated in form of individual criteria. Further, urban and rural areas will be indexed by “n” , $N_j^n(t)$, $n \in \{n\} \equiv \{$**Urban, Rural**$\}$.

Industry:

$\Phi^v(t)$- sector’s assets [billion $],

$p^v(t)$ – producing capacities of selected economic sectors [million $/year],

$Y^v(t)$ – volume of gross output,

$c^v(t)$ – production value,

$v \in \{v\} \equiv \{$**Industry, AgroIndustry, Services, Agriculture**$\}$.

In case of agricultural production, when v = **Agriculture,**

$$p^v(t) = \sum_{j \in \{j\}} \sum_{y \in (Y)} c^y(t) \times Y_j^y(t)\,;$$

Other sectors’ notations correspond to the above-mentioned.

Personal income:

$d_j^n(t)$ - $\forall j \in \{j\}, n \in \{n\}$ – income per person in urban and rural areas generated by the results of general economical activity in the province [$/person].

Flows:

For description of entities, the following set of flows is considered

Water flows:

$f_{\{r\},j}^{k,w\_f}(t)$ – flows of clean water,

$f_{j,\{r\}}^{k,w\_d}(t)$ – discharge of wastewater,

Here w_f , w_d is indexing of clean water flows and waste water flows, respectively; $\{r\}$ is river system structure, j is number of district, and index “k” runs through six directions of water distribution, $k \in \{$ **Urban, Rural, Industry, AgroIndustry, Services, Agriculture** $\}$.

Electric energy flows:

$f^{k,E}(t)$ – electric energy flows to municipal economy,

Here E is indexing of electric energy flows.

Financial flows:

$f_j^{k,\Phi}(t)$ – financial flows to municipal economy,

Production flows:

$f_j^{n,Y}(t)$ – agricultural production flows to the consumer goods basket,

$f^{v,Y}(t)$ – agricultural production flows to agro-industry,

Migration flows:

$f_j^{rural,urban}(t)$ – migration flows from rural area to city within the territory of district,

$f_{j,0}^{,urban}(t)$ – migration flows from district's cities to the center.

Control variables:

The main control variable in the model is a value of gross product, GP, formed by all economic sectors, while other control variables are determined as various relationships as applied to specific branches.

Indicators:

- water supply in municipal economy,
- water supply in industrial sector,
- volumes of gross output per sector,
- gross domestic volume in the province, GDP,
- personal income (urban and rural population),
- food provision,
- employment.

4.3 Regional demography

According to scenarios of socio-economic development in ChAKB, we consider two options of population growth, different for urban and rural areas. Let denote this growth by $\varepsilon^{n,S}$ = (natality - mortality). Then, to determine district's population dynamics, according to scenario "S", the following equation may be used:

$$N_j^{rural,S}(t) = N_j^{rural,S}(t-1) \times (1+ \varepsilon^{rural,S} + \xi^{rural,S}) - f_j^{rural,urban}(t)$$

$$N_j^{urban,S}(t) = N_j^{urban,S}(t-1) \times (1+ \varepsilon^{urban,S} + \xi^{urban,S}) + f_j^{rural,urban}(t) - f_{j,0}^{,urban}(t) \quad (4.1)$$

$$N_0^{urban,S}(t) = N_0^{urban,S}(t-1) \times (1+ \varepsilon^{urban,S} + \xi^{urban,S}) + \sum_{j\in\{j\}} f_{j,0}^{urban}(t)$$

where: S - index of selected scenario, $\varepsilon^{n,S}$ – annual population growth, f_j $f_{j,0}$ – migration flows from rural area to cities and from cities to the center (may be taken from available trends or from special formula, depending on relative difference of incomes in the cities), $\xi^{n,S}$ – accidental variable, with average value of zero and uniformly distributed in the interval [$\pm\, \varepsilon^c$].

$$f_j^{rural,urban}(t) = \alpha^N \times N_j^{rural,S}(t-1) \times (D_j^{urban}(t) - D_j^{rural}(t)) / (D_j^{urban}(t) + D_j^{rural}(t)) \quad (4.2)$$

$$f_{j,0}^{,urban}(t) = \alpha^{N0} \times N_j^{urban,S}(t-1) \times (D_0^{urban}(t) - D_j^{urban}(t)) / (D_0^{urban}(t) + D_j^{urban}(t)) \quad (4.3)$$

Hereinafter, index "0" denotes the center; α^{N0} , α^{N0} are coefficients of migration village→city and city→center, respectively; $D_j^n(t)$ is personal income.

For each district "j", first, we determine two (separately for urban and rural residents) five-component vectors of standard required resources $\mathbf{r}_j^n(t)$, $n \in \{n\}$. The components of the vector are:

- municipal water, norm [l/person/year],
- electric energy for population, norm [kW/person/year],
- consumer goods basket, norm (list of foodstuff [x^k/person/year] and re-calculated in kilocalories [kcal/person/year]),
- residential area, norm [m^2/person].

- rest of consumer (technical) goods basket [$/person/year].

Taking into account that the sequence $N_j(t)$ is specified for the whole simulation period {t}, district resources required for municipal sector are defined as:

$$\mathbf{R}_j^n(t) = N_j^n(t) \times \mathbf{r}_j^n(t) \quad \forall\, n \in \{n\}, j \in \{j\}, t \in \{t\}; \tag{4.4}$$

We will denote district received resources by vector $\mathbf{R}_j^{n,*}(t)$ and difference between demand and actual value by $\delta\mathbf{R}_j^n(t)$.

$$\delta\mathbf{R}_j^n(t) = \mathbf{R}_j^n(t) - \mathbf{R}_j^{n,*}(t),\ \ \delta\mathbf{R}_j^n(t) \geq 0; \tag{4.5}$$

These differences are caused by both objective factors, for example, breaks in water or energy supplies and subjective factors, such as financial abilities of population determined by their actual income.

Values

Based on vectors of standard required resources, we will introduce two (separately for urban and rural residents) five-component vectors $\mathbf{c}^n(t)$ that represent a unit value of respective resources in given point of time "t". The absence of district index of the vectors means that those are common for the whole province but different for urban and rural areas. The third component of vector $\mathbf{c}(t)$- value of the consumer goods basket, is determined as the total value of constituent goods:

$$c_3^n(t) = \sum_k c_k^n(t) \times x^k\ ; \tag{4.6}$$

where: x^k – norm of k–type good in the consumer goods basket, $c_k^n(t)$ – its value in given point of time; this value is different for cities and rural area.

Costs

Minimum costs per person for living under given conditions may be written as a scalar product of vectors "r" and "c".

$$\Phi_j^{N,n}(t) = \mathbf{c}^n(t) \bullet \mathbf{r}_j^n(t), \tag{4.7}$$

In formula (7) $\mathbf{c}(t)$ is row vector and $\mathbf{r}(t)$ is column vector.

4.4 Dynamics of producing capacities

As mentioned in section 1, an input parameter of each economic sector is gross output in all sectors, which contributes to given dynamics of gross domestic product $\Phi^{VVP,v}(t)$. For each sector under consideration, GDP value may be presented in different ways: as existing ratio of GDP to GP, as the most simple, and accepted by us. We have:

$$\Phi^{VVP,v}(t) = \alpha^v \times p^v(t),\ \alpha^v < 1\ . \tag{4.7}$$

Distribution pattern and dynamics α^v per sector is shown in Figure 4.2, while their average are taken from Table 4.1. Estimation of GDP as a difference between GP and costs derived from balance equations usually referred to as V.V.Leontiev's equations is made by the following equation:

$$\Phi^{VVP,v}(t) = p^v(t) - \Phi^{A,v}(t) - \Phi^{R,v}(t); \tag{4.8}$$

where $\Phi^{A,v}(t)$, $\Phi^{R,v}(t)$ are depreciation charges and resource inputs, respectively. However, such approach demands for detailed economic data on each industry, and we have such data only on agriculture.

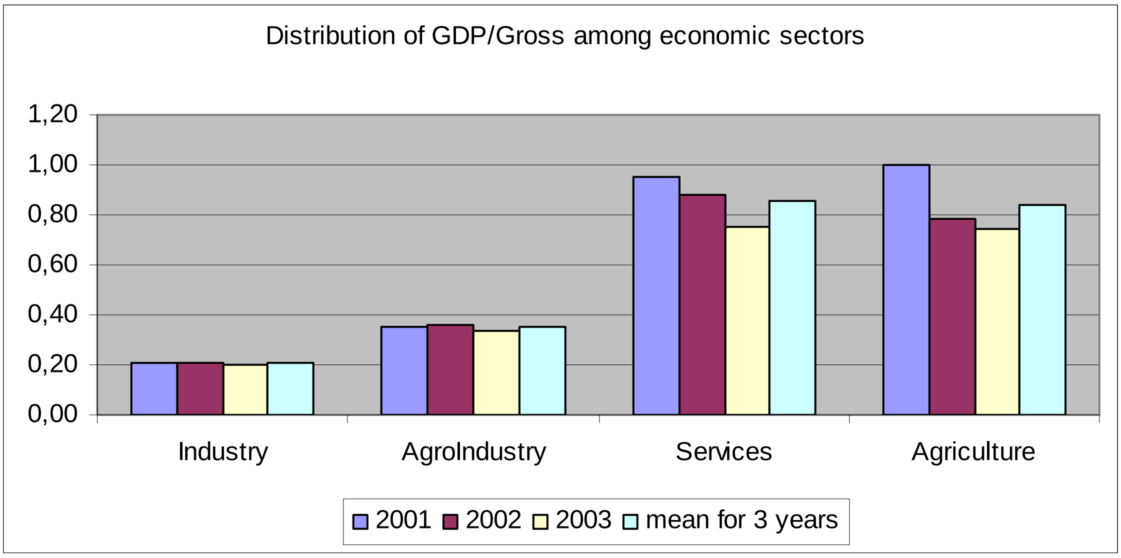

Figure 4.2 α^v distribution dynamics per economic sector

Table 4.1

Industry	AgroIndustry	Services	Agriculture
0,21	0,35	0,86	0,84

High proportion of α^v in services is explained by large shares of labor and employment in this sector and by relatively low capital costs and material inputs, unaccounted capital investments of owners. In agriculture, this proportion results from subsidies into the sector and, at the same time, from shortcomings in current cost accounting in private and cooperative agricultural sectors.

The basic equation for producing capacity dynamics is:

$$\frac{dp^v}{dt} = -\lambda^v p^v + \mu^v(\Phi^v + \Phi_0^v); \qquad (4.9)$$

where: λ^v- coefficients of producing capacity deterioration (differ among economic sectors), μ^v – coefficient of producing capacity increase depending on size of investments, Φ^v , $\Phi_0{}^v$ – investments directed to v –sector from the province and the center, respectively. Difference operator used in the model for approximation of the equation (9) is as follows:

$$p^v(t) = p^v(t-1)\times(1-\lambda^v) + \mu^v\times[\Phi^v(t) + \Phi_0{}^v(t)]; \qquad (4.10)$$

During model calibration, equation (10) must be solved for λ^v and μ^v, thus we get:

$$\lambda^v = \frac{p^v(t-1) - p^v(t) + \mu^v\times[\Phi^v(t) + \Phi_0^v(t)]}{p^v(t-1)}; \qquad (4.11)$$

$$\mu^v = \frac{p^v(t) - p^v(t-1)\times(1-\lambda^v)}{\Phi^v(t) + \Phi_0^v(t)}; \qquad (4.12)$$

By using statistical data on dynamics of gross production and investments volumes in economic sectors for learning period 1990 – 2003 (Figure 3), we will get values of coefficients (Table 4.2) that should be considered quite incorrect!! (For the first three sectors these coefficients are over-estimated by approximately 5 – 7 times, while for agriculture these are under-estimated almost by 20 times).

(Incorrect coefficients) Table 4.2

	Industry	**AgroIndustry**	**Services**	**Agriculture**
λ^v	0.101	0.113	~	0.002
μ^v	0.31	0.39	~	0.0018

In the introduction we mentioned already about risk of using statistical time series (trends) that were obtained by uncontrolled economic experiments. We have just got into such situation. In order to understand why the obtained values of coefficients are incorrect, first, we will write the gross volume of output as a product of physical volume of conventional unit output and its current value, i.e. $p^v(t) = V^v(t)\times c^v(t)$. We determine value $p^v(t)$ from its value in previous point of time (t -1) by expanding into Taylor series and holding the first-order values:

$$p^v(t) = p^v(t-1) + c^v(t-1)\times[V^v(t) - V^v(t-1)] + V^v(t-1)\times[c^v(t)- c^v(t-1)]; \qquad (4.13)$$

Under relatively stable economic conditions, the second term in equation (13) is small and the whole production dynamics is determined by quantity of produced physical values; however, under inflation, the picture is quite different. Setback in production may be observed even under increase of physical output volumes (the second term in (13) plays dominating role when $c^v(t) < c^v(t-1)$). Since it is unreal to have a full idea from statistical reports of downswing dynamics under inflation, we need to use indirect assessments made under controlled economic experiments. To this end, we will select three main elements that form the macroeconomic indicators:

- natural aging of capital assets - $\lambda^{\Phi,v}$
- product price drop dynamics - $\lambda^{c,v}$
- increase in resource cost - $\lambda^{R,v}$

Estimations of λ^v for the first two economic sectors may be obtained on the basis of USSR's State Standards, that are similar to analogous coefficients used by D.Forrester [2] in assessing rates of capital assets deterioration. In case of agriculture, the estimation of coefficient would be based on works done by SANIIRI Institute and SIC ICWC for Central Asian region. We have:

$$\lambda^{\Phi,v}=0{,}03 \pm 0{,}005;$$
$$\lambda^{R,v}=0.04 \pm 0{,}005;$$

Value of $\lambda^{c,v}$ is selected during calibration of the model. Thus, instead of equation (10), we will get:

$$p^v(t) = p^v(t - 1)\times(1 - \lambda^{\Phi,v}) \times(1 - \lambda^{c,v}) + \mu^v\times[\Phi^v(t) +\Phi_0^v(t)]; \qquad (4.14)$$

The corrected coefficients are shown in Table 4.3:

Table 4.3

	Industry	**AgroIndustry**	**Services**	**Agriculture**
λ^v	0.028	0.032	~	0.036
μ^v	0.125	0.135	~	0.138

Figure 3 shows dynamics of production volumes per sector for 1990-2003.

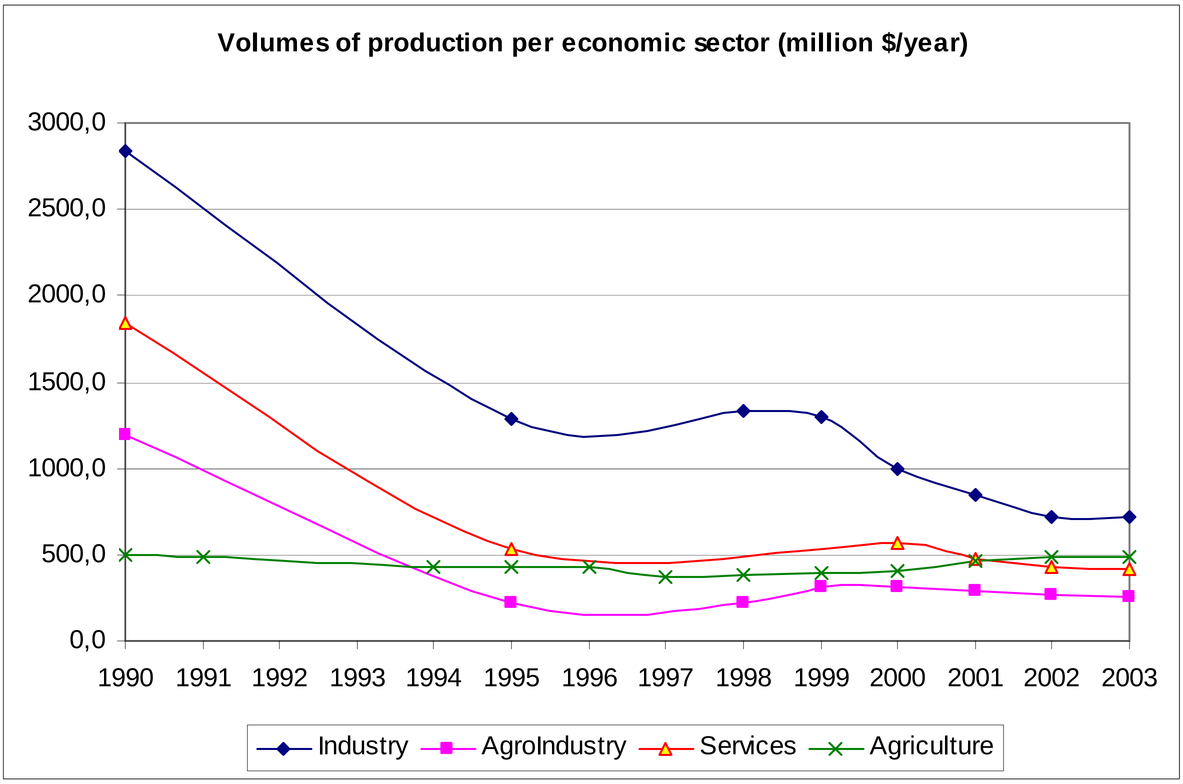

Figure 4.3. Dynamics of production volumes per sector for 1990-2003.

Value of GDP is comprised of two components – profit and workman salaries.

$$\Phi^{VVP,v}(t) = \Phi^{P,v}(t) - \Phi^{S,v}(t); \quad (4.15)$$

Profit, which share can be used by producer for development of producing capacities, together with depreciation charges form producer's own investment. Figure 4.4 shows the distribution functions ξ^{v} of the selected economic sectors as shares of total GDP for Tashkent province in 2003 and the average for 1990 – 2003.

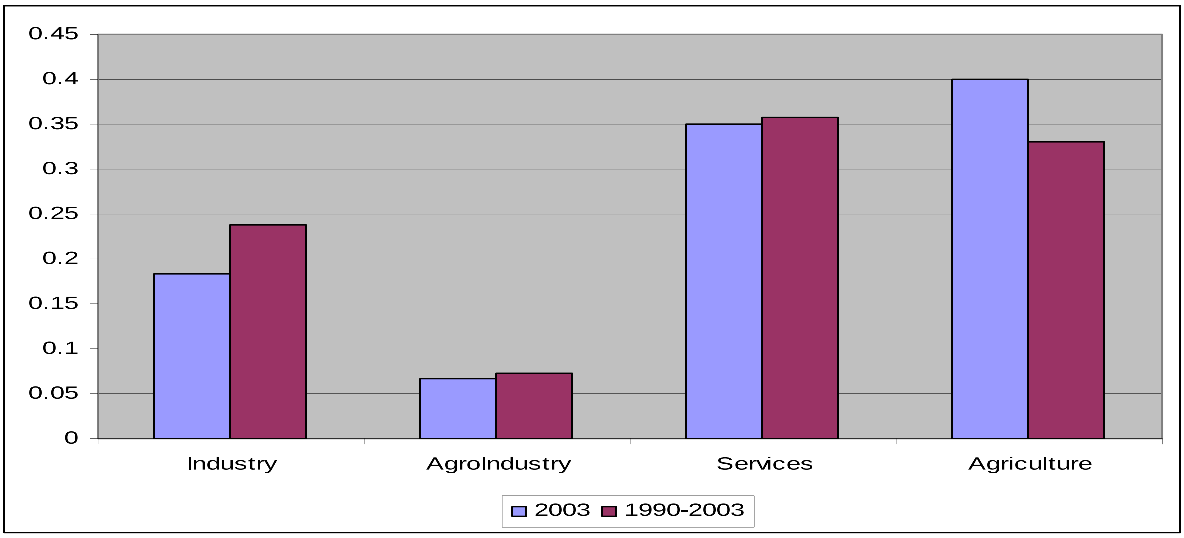

Figure 4.4. GDP distribution functions for 2003 and the average for 1990 – 2003.

If intensive development of any sector is planned in selected scenario, this is realized by re-calculating function $\xi^{v} = \xi^{v}(t)$, which becomes a variable of time.

4.5 Water balance of economic sectors

Annual water balance of economic sectors is formed from sector and district water requests in linkage to distribution network of canals taking water from the three rivers – Chirchik, Akhangaran and Keles. According to spatial lock-on of economic sectors, equations of annual water balance are as follows:

$$\sum_{v\in\{v^*\}}[p^v(t)\times w^{P,v}] + \sum_{j\in\{j+\}}[\Omega_j(t)\times w_j^{\Omega}(t) + \sum_n [N_j^n(t)\times w^{N,n}(t)]] - \sum_{r\in\{r\}}\sum_{j\in\{j+\}}[\sum_{n\in\{n\}} f_{r,j}^{n,w\_f}(t) + \sum_{v\in\{v\}} f_{r,j}^{v,w\_f}(t)] = \delta W(t) \qquad (4.16)$$

District water balances per season (growing, non-growing):

$$\Omega_j(t)\times w_j^{\Omega}(t) + \sum_n N_j^n(t)\times w^{N,n}(t) - \sum_{r\in\{r\}}[\sum_{n\in\{n\}} f_{r,j}^{n,w\_f}(t) + \sum_{v\in\{v\}} f_{r,j}^{v,w\_f}(t)] = \delta W_j(t); \forall j\in\{j\}, \qquad (4.17)$$

Load on treatment plants (v = **Ecology**):

$$p^v(t) > \sum_{v\in\{v^*\}} p^v(t)\times w^{P,v} + \sum_{j\in\{j+\}}\sum_n [N_j^n(t)\times w^{N,n}(t)]; \qquad (4.18)$$

5 EQUATIONS FOR AGRICULTURAL SECTOR

Formal description of agricultural sector functioning and development is based on the theory of complex dynamic systems, where interaction of elements of different physical natures is described either by ordinary differential equations or by special functions obtained through various physical or economic experiments.

A need for development of specialized modeling set, which describes dynamics and evolution of agriculture has arisen from difficulties in using the models set SLISIS – EPIC, proposed by coordinator, for a number of reasons to be explained in details by Dr. Stulina G.V. in her report for this set of models:

- EPIC includes many detailed soil, climatic, technological and other data that require the huge efforts of field studies and literature and the adaptation of coefficients for each crop;
- To use mean values for whole area, as was proposed by modeling recommendations of our partners, can create big error taking into account big unevenness of farming conditions in different zones of sub-basin;
- EPIC does not cover output of socio-economic development indicators in rural area as a result of changes in agricultural productivity, and particularly possibility to balance incomes and required investments for development in order to run our development scenarios.

In this context, it was decided to develop our own set of agricultural development models, which includes dynamics of terrain, state of irrigation systems, linkage with agro-industry and associated sectors. More attention is paid to assessing possibilities to ensure the consumer goods basket and levels of personal income from agriculture, livestock production, homestead plots, etc.

5.1 Dynamics of terrain development

Let denote the current time by "t", and for indexing of districts we introduce a set {j}, j ∈ {j} ≡ {Akkurgan, Akhangaran, . . . Yangiul}- set of districts in Tashkent province. Variable $\Omega_j(t)$ denotes the total area of each district. The upper index "$^{\Omega}$" is used for labeling a set of terrains within a district[1], "$^{\Omega}$" ∈ {$^{\Omega}$} ≡ {irrigated area, dry land, pastures and meadows, ponds and fish hatcheries, homestead land, forest}. Here obvious equation is true:

$$\sum_{\Omega\in\{\Omega\}} \Omega_j^{\Omega}(t) = \Omega_j^{*}(t) \le \Omega_j(t) = ,\ \forall\ j \in \{j\},\ t \in \{t\}; \tag{5.1}$$

where $\Omega^*_j(t)$ is the total district area usable in agricultural production. As urban areas expand, the usable area decreases. In given project, development of urban areas is based on trends; therefore, the following chain:

$$\Omega^*_j(t\text{-}1) \le \Omega^*_j(t) \le \Omega^*_j(t+1),\ \forall\ j\in\{j\}, t \in \{t\}\ ; \tag{5.2}$$

may be considered as a priori.

The basic equation used for description of terrain development dynamics consists of three elements:

- terrain degradation,
  - natural (soil erosion caused by natural and climatic factors),
  - degradation caused by human activities (irrigation erosion due to breach of irrigation regime, mechanical destruction of soil surface's natural structure due to heavy equipment, chemical destruction of soil structure as a result of wrong fertilizer and chemicals application),
- land restoration,
  - natural, through biocenosis,
  - artificial soil restoration by means of soil-aggregating chemicals (by mobilizing finances),
- terrain development,
  - artificial expansion of area of given type at expense of another area through investments.

$$\frac{d\Omega_j^{\Omega}}{dt} = -\Omega_j^{\Omega} \times (\lambda^{\Omega,N} + \lambda^{\Omega,A}(I^A) - \beta^{\Omega,N}) + \frac{s_j^{\Omega}(t)\times\Omega_j^{\Omega} + \Phi_j^{\Omega}(t)}{c^{\Omega}},\ \forall\ \text{“}\Omega\text{”}\in\{^{\Omega}\},\ t\in\{t\}; \tag{5.3}$$

where $\lambda^{\Omega,N}$ is natural rate of degradation of $^{\Omega}$–type terrain [1/year], $\lambda^{\Omega,A}(I^A)$ is rate of man-caused degradation of $^{\Omega}$–type terrain, I^A is intensity of human impact, s_j^{Ω} is a cost per unit allocated for $^{\Omega}$–type terrain preservation [$/ha×year], Φ_j^{Ω} are financial flows [$/year] to development of $^{\Omega}$–type terrain in the district "j", [$/year], c^{Ω} is cost per unit of $^{\Omega}$–type terrain development [$/ha], $\beta^{\Omega,N}$ is the rate of natural restoration of $^{\Omega}$–type terrain [1/year].

Let consider conditions of stable system equilibrium, $d\Omega/dt = 0$; if there is no artificial expansion of area, we will assume $\Phi_j^{\Omega}(t)= 0$, then in order to keep equilibrium:

$$(\lambda^{\Omega,N} + \lambda^{\Omega,A}(I^A) - \beta^{\Omega,N})\times c^{\Omega} - s_j^{\Omega}(t) = 0; \tag{5.4}$$

In equation (5.4), $\lambda^{\Omega,A}(I^A) > 0$, therefore the standard costs $s_j^{\Omega}(t)$ needed for terrain preservation will increase with intensification of man impact. At current level of anthropogenic impact "I^A"

[1] Double semantics applied to one symbol is connected with large quantity of variables in the model. Therefore, to avoid confusion, the upper index of variable will always reflect belonging to the set of variables of given type – this is one of advantages of GAMS language.

the value $\lambda^{\Omega,A}(I^A) \approx 0.03 \pm 0.01$. As to values of $\lambda^{\Omega,N}$ and $\beta^{\Omega,N}$, only the difference is known, i.e. $(\lambda^{\Omega,N} - \beta^{\Omega,N}) \approx \pm 0.01$; for ChAKB upstream the difference is positive (mainly because of big terrain slopes), whereas for mid- and downstream it is negative (restoration processes dominate over degradation. From (5.4) follows that in the equation (5.3) only four parameters may be independent out of five ones: investments Φ, and any three of four parameters – "c", "s" , "λ^N" , and "λ^A". At present, for the Tashkent province, value of "c^Ω" is ≈ 4000 \$/ha, (this value is used for future simulations), and, consequently, for s_j^Ω we have ~ 120 \$/ha. For correct reflection of the sequence in costs and investments, equation (5.3) is re-written in difference form:

$$\Omega_j^\Omega(t+1) = [1- \lambda^{\Omega,N} - \lambda^{\Omega,A}(I^A(t)) + \beta^{\Omega,N} + s_j^\Omega(t)/ c^\Omega]\times\Omega_j^\Omega(t) + \Phi_j^\Omega(t+1)/ c_j^\Omega ; \qquad (5.5)$$

Here "t+1" and "t" are current year and past year, respectively.

5.2 Dynamics of irrigation systems and irrigation technique

The state of irrigation systems that supply water for crop plays an important role in irrigated areas. The overall indicator of the state of irrigation systems is coefficient of efficiency, which is determined as a ratio between the water discharge in outlet from the irrigation system and the water discharge in inlet. As earlier mentioned, besides coefficient of efficiency, irrigation systems are characterized by maximum capacity; however, for irrigation systems considered in given project, this indicator is practically always satisfied. Therefore, only indicator of efficiency will be used in describing degradation and further rehabilitation of the functional capacity of irrigation system. Besides coefficient of efficiency of irrigation system, coefficient of efficiency of irrigation technique reflecting the water use efficiency in the field plays an equally important role in water balance of irrigated area. This indicator is somewhat more difficult to determine since it relates to two types of losses, that is percolation and surface outflow from field. The product of these two coefficients of efficiency gives the total water losses from head intake to plant. Let denote coefficient of efficiency by "η" and introduce, similar to previous section, a set of systems $\{^\eta\} \equiv$ {irrigation systems-"can", irrigation technique-"field"}. Dynamics of irrigation systems and irrigation technique may be written in long-term dimension as:

$$\frac{d\eta_j^\eta}{dt} = -\lambda^\eta \eta_j^\eta + \frac{\sqrt{(1-\eta_j^\eta)}}{A^\eta}[s_j^\eta(t) + \Phi_j^\eta(t)], \ \forall\ j \in \{j\},\ \eta \in \{^\eta\},\ t \in \{t\}; \qquad (5.6)$$

where λ^η is the rate of η–system degradation [1/year], s_j^η is cost per unit for maintenance of η–system in the district "j" [\$/ha×year], Φ_j^η is financial flow for maintenance and development of η–system in the district "j" [\$/ha×year], A^η is cost per unit of η–system development [\$/ha].
For present state of irrigation systems in Tashkent province, "η" varies within ~ 0.7 ± 0.02, and maintenance costs "s^η" ~ 40 \$/ha. Experimental study of irrigation system degradation (η="can") results in ~ 0.03 for the parameter "λ^η". By using these values for equilibrium condition (dη/dt = 0), we obtain $A^\eta \approx 1000$ \$/ha for Tashkent province. Approximately the same parameter values are used in irrigation technique of furrow irrigation (parameter values are quite different for drip irrigation and sprinkling).
The following difference operator is used in algorithm for equation (5.6):

$$\eta_j^\eta(t+1) = (1-\lambda^\eta)\times\eta_j^\eta(t) + \{[(1-\eta_j^\eta(t))^2]\times s_j^\eta(t) + [(1-\eta_j^\eta(t+1))^2] \times\Phi_j^\eta(t+1)\}/A^\eta; \qquad (5.7)$$

Here "t+1" and "t" are current year and past year, respectively.

5.3 Soil dynamics

Soil water-physical parameters change very slowly; therefore, they are used as basic constants for given district, while assessment of dynamics of soil fertility deterioration and restoration is based on dynamics of four main constituents: humus; nitrogen; phosphorus; and, potassium. Consequently, the state of soil "S" may be characterized by a vector of four constituents:

H – amount of humus in the soil [t/ha],
N - amount of nitrogen in the soil [kg/ha],
P - amount of phosphorus in the soil [kg/ha],
K - amount of potassium in the soil [kg/ha].

As before, we introduce the set {S}≡ {H, N, P, K}. We are considering changes in soil fertility as a result of the following factors:

- environmental-driven fertility decrease (wind, rainfall),
- irrigation-driven removal of elements,
- uptake of elements by crops,
- fertility improvement as a result of natural generation of elements,
- fertility improvement through artificial application of elements.

By writing gradually impacts of all above mentioned factors, we obtain the following vector differential equation:

$$\frac{dS_j^S}{dt} = -\{\lambda_j^S + \sum_{y\in\{Y\}} \xi_j^y(t) \times [\beta_j^S (1-\eta_j^\eta) w_j^y(t) + \gamma^{S,y} Y_j^y(t)]\} \times S_j^S$$
$$+ \sum_{y\in\{Y\}} \mu^{S,y} \xi_j^y(t) Y_j^y(t) + \frac{\Phi_j^S(t)}{c^S}; \;\; \forall\, j\in\{j\},\, S\in\{S\},\, t\in\{t\}; \qquad (5.8)$$

where λ_j^S is the rate of environmental-driven degradation of S–component [1/year], β_j^S is a share of S–component removed because of irrigation [1/m^3], η_j^η is efficiency of irrigation technique in the district "j", w_j^y(t) is amount of water delivered for crop "y" [м3/ha×year], $\gamma^{S,y}$ is a share of S–component absorbed by crop "y" [1/c], Y_j^y is biomass of crop "y" in the district "j" [tn/ha×year], $\mu^{S,y}$ is multiplication of a share of crop "y" biomass remained in the soil after harvesting by the rate of component "S" generation from these residues, Φ_j^S (t) is cost per unit of S–component conservation in the district "j" [\$/ha×year], c^S is the cost of S–component [\$/t, \$/kg], ξ_j^y is the share of land under crop "y" in the district "j", which reflects cropping pattern, see next section.

The difference form of equation (5.8) used in algorithm is:

$$S_j^S(t+1) = (1 - \{\lambda_j^S + \sum_{y\in\{Y\}} \xi_j^y(t) \times [\beta_j^S (1-\eta_j^\eta(t)) w_j^y(t) + \gamma^{S,y} Y_j^y(t)]\}) \times S_j^S(t)$$
$$+ \sum_{y\in\{Y\}} \mu^{S,y} \xi_j^y(t) Y_j^y(t) + \frac{\Phi_j^S(t+1)}{c^S}; \qquad (5.9)$$

Here "t+1" and "t" are current year and past year, respectively. Numerical values of soil fertility are estimated using N.V.Kimber's work [8] and calibrated on the basis of research as conducted by P.V.Protasov and F.K.Kadyrkhodjayev [4].

The larger amount of humus is accumulated in the upper horizon (0-30 cm), with further decrease in depth. In typical soil, the humus layer is 50 cm, reaching 100 cm in highly cultivated land. In spring and early summer, humus content slightly decreases in the soil because of its mineralization processes. In autumn, when roots die and leaves fall, humus is intensively generated. Through decomposition of root and stubble remains, the annual influx of organic

matter in the soil is 2 – 3 t/ha in Tashkent province; after alfalfa and grass - 4 – 5 t/ha, and leaves and plant stem residues add another 1 t/ha.
Humus content in the soil (0-100 cm) is distributed as follows:

1. Desert zone (<200m above-sea level) 0,3 – 0,5 – 1% (30 – 40 – 60 t/ha)
2. Light sierozem (200 – 350m above-sea level) 0,8 – 1,2 – 1,5% (50 – 60 – 70 t/ha)
3. Typical sierozem (350 – 600m above-sea level) 1,5 – 2,0 – 2,3% (70 – 90 t/ha)
4. Dark sierozem (600 – 1200m above-sea level) 2,3 – 2,8– 3,5% (90 – 130 t/ha)

Augmentation of nutrients in the soil may take place due to certain micro-organisms; for example, azotobacters (microbes) residing in the soil can accumulate to 15 – 30 kg of pure nitrogen per hectare a year by adsorbing nitrogen from the atmosphere. Nodule bacterium (residing on the roots of legumes, alfalfa, clover) can uptake nitrogen from air and accumulate up to 60 – 100 kg of pure nitrogen per hectare a year.

Removal of H, N, P, and K from the soil is referred to negative part of fertility balance. For our calculations, removal values of NPK per 1 t of harvest, as expressed in kg/t and removal values of NPK per 1 ha, as expressed in kg/ha are those shown in Table 5.1.

Table 5. 1

Crop	Total removal of NPK					
	N(kg/ha)	N(kg /t)	P_2O_5(kg/ha)	P_2O_5(kg /t)	K_2O (kg/ha)	K_2O (kg /t)
Winter wheat	130	37	46	13	80	23
Corn	303	34	102	12	313	37
Rice	224	28	104	13	272	34
Cotton	100.2	40	29.9	12	119.6	35
Root	200	5.2	63	1.8	230	7.5
Vegetables	110	2.8	60	1.2	170	3.9
Grass (alfalfa)	500	26	130	6.5	250	15
Potato	155	6.2	75	2	360	10.5
Cucurbits	180	3	100	1.5	200	6.5
Kenaf	100	11	41	6	119	22

5.4 Crop dynamics

Crop dynamics in the long-term is described by function of crop distribution over given area. Three terrain types are stipulated in the project for crop production. Those are: {Irrigated area, Dry land, Homestead plots}. Each crop may have several plots, but is characterized by the total area of all plantations. By using the earlier assigned labeling for the distribution, we will have:

$$\xi_j^{y,\Omega}(t) = \frac{\Omega_j^{y,\Omega}(t)}{\Omega_j^{\Omega}(t)}; \qquad \sum_{y\in\{Y\}} \xi_j^{y,\Omega}(t) = 1, \forall\ j \in \{j\},\ \Omega \in \{\Omega\},\ t \in \{t\}; \qquad (5.10)$$

Within-year crop dynamics is determined by plant growth under the influence of the following main factors:

- conditions of soil under crop,
- variable costs allocated for given crop,
- climatic factors:
    - rainfall,
    - temperature,
- accessibility of groundwater,
- water supply through irrigation systems.

Plant biomass, Y, is considered as the main parameter for description of within-year crop dynamics. This biomass is comprised of root biomass, Y^R, and above-ground biomass, $[Y - Y^R]$. Besides, we will introduce harvest output coefficient, k^y. Then, depending on crop grown, the yield corresponding to the PY will be determined by the following expressions:

$$Y^H = [Y - Y^R]\times k^y \text{ or } Y^H = Y^R\times k^y ;\quad 0 \le k^y \le 1\ \forall\ y\in \{Y\}; \qquad (5.11)$$

Here, as earlier, {Y} is the set of crops grown. The second expression (5.11) is used for calculation of root yields. Table below shows the relations between main product and by-product per crop that were used in our calculations.

Table 5.2

Crop	Relation between main product and by-product under given yield		Yield (tn/ha)
Winter wheat	1 1.5	grain straw	4 6
Corn	1 2	grain stems	10 20
Rice	1 1.6	grain straw	6 9.6
Cotton	1 2.4	fiber stems	2.5 6
Roots	1 0.7	roots tops	40 28
Vegetables	3 1	fruit tops	16 5.3
Grass (alfalfa)	1	straw	20
Potato	1 1	tuber tops	20 20
Cucurbits	3.5 1	fruit tops	35 10
Kenaf	1	stems	15

In crop production practice, there is a term «potential crop yield», which takes into account zonal climatic conditions and long-term soil fertility indicators, see section 3.1 «Crop». The potential yield is determined mainly by soil water-physical characteristics and humus content, $Y^{0,y}(H)$. The impact of climatic factors contributing to biomass and yield formation are viewed in light of PY change as resulted from high or low effective temperatures for specific crop. To this end, we will introduce variable, τ, which reflects intra-annual time, then the impact of positive temperature variations on biomass formation can be written as:

$$Y^{P,y}(T^{\Sigma}) = Y^{0,y}(H) + \frac{\partial Y^{y}}{\partial T}(T^{\Sigma} - T^{\Sigma 0,y}) \quad (5.12)$$

where $T^{\Sigma,y}$ is the sum of effective temperatures for major plant development phases, $T^{\Sigma 0,y}$ is the basic value of the sum of effective temperatures for crop, y, under consideration [12,13].

$$T^{\Sigma}(\tau) = \int_0^{\tau}(T(\zeta) - T^{*,y})d\zeta\,; \quad (5.13)$$

$T^{*,y}$ is the temperature threshold for crop, y.
Thus, the value of PY is adjusted by using formula (5.12) to the value of really possible yield (DVY), which can be obtained on specific area under actual climatic conditions. In order to calculate actual possible yield, YH, as a function of mineral fertilizers available in the soil in given point of time, t, we will introduce the auxiliary variable, $u^{y}(S)$, which is determined as follows:

$$u^{y}(S) = \frac{\sum_{S\in\{S^*\}} \alpha^{S,y} x^{S,y}}{\sum_{S\in\{S^*\}} \alpha^{S,y}}\,; \quad (5.14)$$

$$x^{S,y} = \frac{m^{S,y}}{m0^{S,y}}\,; \quad (5.15)$$

where {S*} = {N, P, K} – fertilizer composition, since humus effect is considered in formula (5.12), $m^{S,y}(t)$ and $m0^{S,y}$ – actual (for given point of time) and standard mass of S–component in the soil, respectively, $\alpha^{S,y}$- coefficient of fertilizer significance in development of y-crop biomass. The above-mentioned coefficients were estimated through analysis of field data [4].
The equation for specific possible yield of biomass under given quantity of fertilizers in the soil is based on experimental data and has the following form:

$$Y^{P,y}(S) = Y^{P,y}(T^{\Sigma}) \times u^{y}(S) \times \boldsymbol{exp}[-u^{y}(S)]; \quad (5.16)$$

The equation for $k^{P,y}(S)$ is similar:

$$k^{P,y}(S) = k^{0,y}(H) \times v^{y}(S) \times \boldsymbol{exp}[-v^{y}(S)]; \quad (5.17)$$

Variable $v^{y}(S)$ is calculated by formula (5.14) but with different coefficients of fertilizer's role.
Function of variable costs effect[2] on yield generation is a composite one, where the reference point is a possible value obtained from the equation (5.16):

$$Y^{P,y}(S,\Phi^{y}) = Y^{P,y}(S) \times \frac{\gamma^{y} \times \Phi^{y}}{(\gamma^{y} - 1) \times \Phi^{0,y} + \Phi^{y}}\,; \quad (5.18)$$

where: Φ^{y} , $\Phi^{0,y}$ – actual and standard variable costs, respectively, of given crop y under specific conditions, γ^{y}. – crop parameter, which is determined as γ^{y} = PY/YH. Relationship between the productivity level and the variable costs was determined from WUFMAS Project's data, as well as from actual statistical data.
The required irrigation norm is defined as the difference between the crop evapotranspiration $q_j^{y}(\tau)$ and the total rainfall $q_j^{p}(\tau)$ plus groundwater contribution $q_j^{g}(\tau)$; consequently, the amount of water diversion required for crop during the growing season may be re-written as:

[2] Cost per unit does not incorporate costs of fertilizers and water.

$$w_j^{y,w} = \int_{\tau^{y,beg}}^{\tau^{y,end}} \frac{q_j^y(\tau) - q_j^p(\tau) - q_j^g(\tau)}{\eta_j^{can} \times \eta_j^{field}} d\tau \; ; \qquad (5.19)$$

Here η_j^{can} , η_j^{field} – efficiency of canals and of irrigation technique, respectively, $\tau^{y,beg}$ $\tau^{y,end}$ - beginning and end of growing season for crop y.

In case of water shortage or abundance, crops also face stress, which is reflected, first, on harvest output coefficient k^y. By considering the cumulative crop stress in form of successive imposition of stresses due to fertilizer and water inputs, final equation for the Actual yield (RY)[3] can be written as:

$$Y^{P,y}(S,\Phi^y,w) = Y^{P,y}(S,\Phi^y) \times f_j^{w,y}(w); \qquad (5.20)$$

where: $f_j^{w,y}(w)$ – stress function due to shortage or abundance of water delivered to irrigated area which determines yield losses because of soil over-drying or over-wetting (yield losses due to over-drying or over-wetting were estimated on the basis of data obtained by E.D.Cholpankulov, see V.A.Dukhovny [3]):

$$f_j^{w,y}(w) = \alpha \times \zeta_j^y \times \boldsymbol{exp(} - \zeta_j^y\boldsymbol{)}; \qquad (5.21)$$

where α – normalization factor, for this formula $\alpha = 2.7182..$, ζ_j^y – relative water quantity for crop, and from formula (3.19), we have:

$$\zeta_j^y = \frac{w_j^{y,w} \times \eta_j^{can} \times \eta_j^{field} + w_j^p + w_j^g}{w_j^y} \; ; \qquad (5.22)$$

here: w_j^y, w_j^p, w_j^g – integral values of evapotranspiration, rainfall, and groundwater contribution, respectively, during the growing season of crop "y" (calculated by CROPWAT program), $w_j^{y,w}$ - quantity of water supplied for irrigation. At the beginning of research, the both efficiency coefficients were considered constant for given district during the whole year. We used database of RiverTwin Project for calibration. While calibrating the model, it was found that only canal efficiency, η_j, may be considered constant during a year. The above assumption was found unacceptable for irrigation technique efficiency, η_j^{field}. This efficiency varied widely for different actual water availabilities in the district. The main cause is human factor – when water is lacked, people start using it carefully, whereas when water is abundant, field runoffs increase considerably. Let denote the quantity of water delivered to irrigation contour by w_j^{can}:

$$w_j^{can} = \eta_j^{can} \times \sum_y \xi_j^{y,\Omega} \times w_j^{y,w} \; ; \; \zeta_j^{can} = \frac{w_j^{can}}{w_j^{*E} - w_j^p - w_j^g} \; ; \qquad (5.23)$$

where $w_j{*}^E$ – weighted average value of evapotranspiration per 1 hectare. In fact, the coefficient ζ_j^{can} describes actual water availability in the district. Let η_j^{field*} be the actual efficiency of irrigation technique, then the actual quantity of water received by crops, w_j^*, and field runoff, w_j^-, are as follows:

$$w_j^* = \eta_j^{field*} \times w_j^{can} \; ; \; w_j^- = (1 - \eta_j^{field*}) \times w_j^{can} \; ; \qquad (5.24)$$

Let η_j^{field} is the mean efficiency of irrigation technique. There is the following relationship between the mean and the actual efficiencies:

[3] One should note that in general case, the formula for the actual yield includes another one function, that is the stress function of soil salinity; however, such soil is absent in the project, and we used the reduced option for calculation of RY.

$$\eta_j^{field*} = \frac{\eta_j^{field}}{\eta_j^{field} + (1-\eta_j^{field}) \times (\eta_j^{field} \times \zeta_j^{can})^N};\qquad (5.25)$$

where the mean value N equals 3/2 for the Chirchik-Akhangaran-Keles basin;
Figure 5.1 shows the function of efficiency and the stress function, depending on actual water availability in the district, which was constructed on the basis of processed field data as collected under RiverTwin project for ChAKB.

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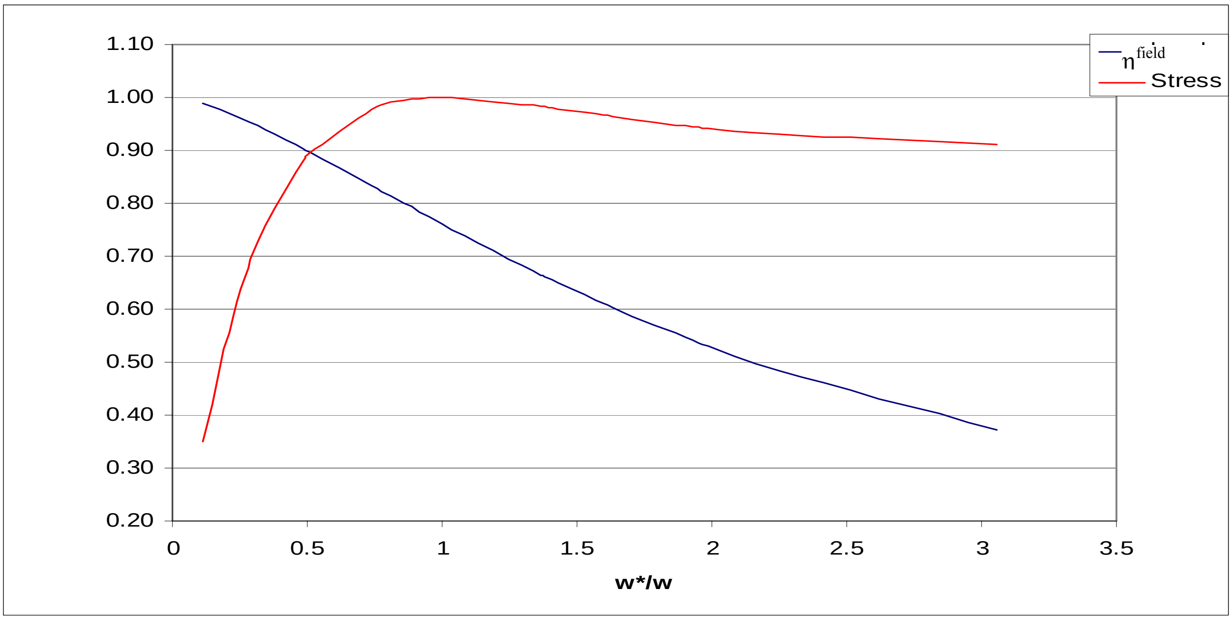

Figure 5.1 Functions of efficiency and stress depending on water availability in the district

5.5 Livestock-breeding dynamics

Livestock-breeding block forms a share in the consumer goods basket and the manure for soil fertility improvement. The main equations of livestock-breeding dynamics are as follows: {r} = {cattle, small ruminants, poultry}

Population dynamics:

$$N_j^r(t+1) = (1 + \alpha^r - \beta^r) \times N_j^r(t) + \frac{\Phi_j^r(t+1)}{c^r};\qquad (5.26)$$

where: α^r – breeding coefficient , β^r - slaughtering coefficient, Φ_j^r – investments for buying cattle, c^r- cost of unit r-cattle,

Dynamics of unit cattle's mass accumulation:

$$M_j^r(t) = M_j^r(t\text{-}1) + k^r \times \frac{2m_j^{y,r}(t)}{m_j^{y,r}(t) + m_j^{y,0r}};\qquad (5.27)$$

where: $M_j^r(t)$ – mass of unit cattle [kg], $m_j^{y,r}(t)$- actual quantity of fodder, including forage from pastures and meadows [kg], $m_j^{y,0r}$ – standard quantity of fodder, [kg], k^r – live weight increase [kg/year].

Meet contribution to the district's consumer goods basket

$$M_j(t) = \sum_r [M_j^r(t) \times \beta^r \times N_j^r(t)];\qquad (5.28)$$

Milk contribution to the district's consumer goods basket

$$M_j(t) = \sum_r [\gamma^r \times N_j^r(t)]; \quad (5.29)$$

where: γ^r – quantity of milk from one cow

The daily need for green fodder:

- ✓ Cows 40 – 75 kg per head
- ✓ Young animal (under one year) 15 – 25 kg per head
- ✓ Young animal (1- 2 years) 30 – 40 kg per head
- ✓ Sheep 6 – 8 kg per head
- ✓ Lamb 2 – 3 kg per head
- ✓ Horse 30 – 40 kg per head.

One cow needs 0,3 ha of cultivated grass-land.

Annual fodder need per 1 head of cattle (centner/year)

Table 5.3

Annual yield of milk (kg/year)	Alfalfa (dry)	Silage	Green maize and vegetable-cucurbits wastes	Roots	Concentrates, mixed fodder
Live weight of cattle head 450 – 500kg					
2000	32.3	38.0	8.0	23.0	3.7
3000	35.0	41.0	13.0	31.0	6.6
4000	37.6	43.0	14.0	38.0	10.4
Live weight of cattle head 501 – 550kg					
2000	35.6	40.0	8.0	33.0	3.7
3000	38.6	43.0	12.0	40.0	6.6
4000	39.3	44.0	15.0	40.0	10.5

Fodder unit concentration in 1 t of product

Table 5.4

Product	Fodder unit concentration
Alfalfa (hay)	550
Silage	210
Green maize, wastes: vegetable, cucurbits	150
Roots	160
Concentrates, mixed fodder	900

1 head needs for fodder units, yearly:

1. Cattle – 3100 fodder units
2. Sheep – 410 fodder units
3. Poutltry – 15 fodder units

Dynamics of waste (manure) generation:

$$m_j^{navoz}(t) = \sum_r k^{r,n} \times N_j^r(t); \qquad (5.30)$$

1 head of livestock generates annually:

- Cattle 4,5 - 6,4 t of dung
- Sheep and goat 1,0 – 1,5 t of dung
- Young cattle (under 2 years) 1,5 – 4,0 t of dung
- Poultry (1000 heads) 10 t of dung

NPK concentration in organic fertilizer

Table 5.5

Organic fertilizer	Kilogram per 1 t of manure		
	Nitrogen	Phosphorus	Potassium
Sheep dung (dry)	16	5	14
Horse dung	5	2.5	7
Cow dung	4	2.5	5
Poultry dung (dry)	34	16	8
Cotton cake	66	28	16
Excrement	5	2	2
Peat	10 -12	2	3 - 8

All numerical coefficients in section 5.5 were derived from the analysis of K.I.Lapkin's material [7].

5.6 Fishery

Fishery is considered only as a factor contributing to formation of the consumer goods basket. Only fish ponds are taken into account since river fish does not contribute to ChAKB's fisheries. Formation of the consumer goods basket:

$$M_j^{fish}(t) = k^{fish} \times \Omega_j^{fish}(t)\ ; \qquad (5.31)$$

where k^{fish} – coefficient of pond productivity [kg/year×ha], $\Omega_j^{fish}(t)$ – total area of ponds [ha] in district "j"

Fishery requirements regarding river:

$$W_j^{inp,fish}(t) = \Omega_j^{fish}(t) \times [E_j(t) + k^{muv} \times h_j^{fish}]; \qquad (5.32)$$

where: $E_j(t)$ - evaporation per unit pond surface, k^{muv} - flowage coefficient of fish ponds, h_j^{fish} – mean pond depth.

5.7 District revenues from agricultural production

Annual district revenue is defined as the difference between the total revenue from agricultural production and the agricultural production costs:

$$D_j(t) = \sum_{\Omega} \Omega_j^{\Omega}(t) \times \{ \sum_{y \in \{Y^{\Omega}\}} \xi_j^{y,\Omega}(t) \times [c^y(t) \times Y_j^{y,\Omega}(t) - s_j^{y,\Omega}(t)] - c^w \times w_j^{\Omega}(t) - s_j^{\eta,\Omega}(t)\}$$
$$+ \sum_{r \in \{R\}} \sum_{v \in \{V^r\}} [c^{r,v}(t) \times M_j^{r,v}(t) - s_j^{r,v}(t)]$$

$$+ c^{fish}(t) \times M_j^{fish}(t) - s_j^{fish}(t) \qquad (5.33)$$

where: $\xi_j^y(t)$ – cropping patterns per irrigated area and dry land, $c(t)$ – current product values, $s(t)$ – cost per unit, $M(t)$ – production mass from livestock-breeding and fishery. Crop production costs are calculated as:

$$s_j^{y,\Omega}(t) = \sum_{\Omega} \Omega_j^{\Omega}(t) \times \sum_{y \in \{Y^{\Omega}\}} \xi_j^{y,\Omega}(t) \times [\Phi_j^{y,\Omega}(t) + \sum_{S \in \{S^*\}} c^S(t) \times S^S(t)]; \qquad (5.34)$$

where: c^S, S^S – cost and quantity of "s" – type fertilizer, respectively.

The net profit, without accounting of taxation, which is equivalent to GDP (Gross domestic product) at the administrative unit level (districts, provinces), is determined as a sum of the annual revenue and the operating personnel salary (production costs were calculated using actual data collected under RiverTwing project). Hence:

$$VVP_j(t) = D_j(t) + Z_j^N(t); \qquad (5.35)$$

where:

$$Z_j^N(t) = c_j^N(t) \times [\sum_{\Omega} \Omega_j^{\Omega}(t) \times \sum_{y \in \{Y^{\Omega}\}} \xi_j^{y,\Omega}(t) \times \tau^{y,\Omega} + \sum_{r \in \{R\}} N_j^r(t) \times \tau^r + \Omega^{fish}(t) \times \tau^{fish}]; \qquad (5.36)$$

where: $c_j^N(t)$ – cost of one man-hour in farm work, τ - the number of standard hours it takes to do respective kind of work (salary of agricultural producer is taken from statistical reports 2003 of the Republic of Uzbekistan). Based on GDP for each volume, we determine GDP of the province and respectively contribution of agro-industry and services to GDP generation. All indicators were summarized in Tables. Tables 5.6 and 5.7 show results of detailed calculation of economic indicators for livestock-breeding and crop production in Tashkent province.

Economic indicators of agricultural block

Table 5.6

Grapes	62.72	120.00	7 526 400		1 569 900	1 569 900
TOTAL for homestead plots			**58 717 113**		**15 627 113**	**15 627 113**
Grand TOTAL for 2003			**226 658 514**	**127 980 357**	**44 446 232**	**172 426 589**
Cashed profit for crop production (Irrigated areas)	Gross harvesting (thousand t)	Value ($ /t)	Gross income ($)	Salary ($)	Profit ($)	GDP ($)
Cucurbits	56.43	21.50	1 213 294	1 095 600	197 513	1 293 113
Grapes	23.04	120.00	2 764 812	3 201 000	345 602	3 546 602
Cereals	431.72	69.00	29 788 411	43 093 600	3 885 445	46 979 045
Potato	136.17	140.00	19 064 254	2 604 150	4 112 432	6 716 582
Kenaf	78.04	93.50	7 297 179	1 931 100	1 209 693	3 140 793
Maize for grain	29.21	75.50	2 205 464	3 187 800	365 143	3 552 943
Maize for silage and green forage	283.43	28.70	8 134 338	4 348 460	1 700 559	6 049 019
Perennial grass of past years for green forage	239.86	23.60	5 660 769	2 229 500	1 319 247	3 548 747
Perennial grass of past years for hay	46.98	71.00	3 335 286	1 305 290	798 590	2 103 880
Perennial grass of current year for green forage	31.76	23.60	749 490	506 500	174 669	681 169
Perennial grass of current year for hay	10.86	71.00	771 121	576 230	184 635	760 865
Vegetables	586.21	60.30	35 348 646	9 385 200	7 210 420	16 595 620
Annual grass	47.59	23.60	1 123 030	901 250	261 723	1 162 973
Rice	32.39	180.00	5 829 518	4 003 300	1 133 517	5 136 817
Fruits	47.99	76.80	3 685 501	4 628 300	1 526 028	6 154 328
Cotton	187.95	200.00	37 589 464	43 584 450	3 044 747	46 629 197
Fodder roots	25.89	30.60	792 263	270 400	170 880	441 280
TOTAL for irrigated area			**165 352 840**	**126 852 130**	**27 640 842**	**154 492 972**
Dry land						
Cereals	17.41	69.00	1 201 152	696 000	331 152	1 027 152
Fodder crops	13.99	30.60	428 073	130 800	264 573	395 373
Perennial grass of past years for green forage	4.41	23.60	104 123	6 364	96 168	102 532
Perennial grass of past years for hay	5.04	71.00	357 485	53 312	290 845	344 157
Perennial grass of current year for green forage	1.04	23.60	24 544	1 942	22 116	24 058
Perennial grass of current year for hay	0.42	71.00	29 749	21 573	2 783	24 356
Annual grass	5.09	23.60	120 167	47 609	60 657	108 265
Cotton	0.63	200.00	125 268	75 600	30 768	106 368
Grapes	1.65	120.00	198 000	95 027	79 216	174 243
TOTAL for dry land			**2 588 561**	**1 128 227**	**1 178 278**	**2 306 504**
Homestead plots	Gross harvesting					
Maize for corn	6.44	75.50	486 220		67 620	67 620
Vegetables	184.83	60.70	11 219 181		2 978 581	2 978 581
Potato	239.20	140.00	33 488 000		8 372 000	8 372 000
Fruits	78.09	76.80	5 997 312		2 639 012	2 639 012

Table 5.7

LIVESTOCK-BREEDING (2003)	Product	Value $/unit	Gross income ($)	Net cost ($)	Profit ($)
Meet, thousand t	72.30	1830.00	132 308 873	105 231 000	27 077 873
Milk,thousand t	356.17	180.80	64 395 898	51 917 000	12 478 898
Eggs, million	419.00	81.50	34 148 761	23 778 000	10 370 761
Wool, t	920.10	394.40	362 887	355 630	7 258
Hides, thousand t	15.80	18.60	293 930	268 000	25 930
TOTAL for livestock-breeding ($)			**231 510 349**	**181 549 630**	**49 960 719**

6 CALIBRATION OF THE SET OF MODELS AND ITS VALIDATION

Construction of such complex modeling set which attempts to simulate various components of socio-economic development in quite diverse, in natural and economic terms, sub-basin, undoubtedly, requires numerous research and statistical data. Before and after national independence, SANIIRI and later on SIC ICWC together with many research institutions in Central Asia have studied specificities of irrigated and dry land productivity formation in the region. These data were generalized in many publications and used for calibration of separate models and of the whole modeling set. Specific references and work undertaken to determine connection coefficients and further validate simulation results are described below.

6.1 General provisions

The main part of modeling set describes functioning of agriculture, which is based on irrigated farming. Here exist many relationships and functional links that describe the effect of various natural and technological factors on land productivity, the changes in water availability and land reclamation processes on the same indicators and some combinations of primary and secondary products. These models may undoubtedly use results obtained before the independence under former research efforts. At the same time, transition period in the economy was taken into account in many works completed recently under projects such as WARMAP [9], A-2 [10] and many others. This allowed consideration of both recent changes and international approaches to socio-economic assessment of agricultural development.

Whereas agricultural mechanisms have adequate theoretical basis, industrial, agro-industrial, and services mechanisms (regularities), with their unstable trends and tendencies may be calibrated only on macro-economic level of entities to be subjected to future planning.

In calibration of agricultural block we used data over the period 1975-1990, and validation was made by comparing simulated and actual data for 2000-2003. Statistical data for 1995-2002 were used for calibration of other blocks, and validation was based on comparison with economic results for the same period of time, particularly 2003, when economic trends became relatively stable.

6.2 Calibration of industrial development and services models.

Parameters in equations 4.1-4.7 were determined on the basis of respective trends accumulated in the data base on Tashkent province, with division into districts (report D24).

Calibration of indicators in equations 4.9-4.14 is based on analysis of statistical data on Tashkent province, as given in section 4.4.

Urban area development (equation 5.2) is determined by trends similar to equations 4.1-4.7. Moreover, degrees of area degradation and restoration (equations 5.3-5.5) are calibrated on the basis of data published in "Drainage in the Aral Sea Basin: towards a strategy for sustainable development ", McGill, HR Wallingford, SIC ICWC, 2004, Tashkent, p. 102-105.

6.3 Validation of agricultural block.

Dynamics of irrigation systems and its indicators – equations 5.6-5.7 – are taken by analogy with other Uzbek systems, on the basis of research under joint SIC ICWC-FAO project (published in "Drainage in the Aral Sea Basin: towards a strategy for sustainable development ", McGill, HR Wallingford, SIC ICWC, 2004, Tashkent, p. 102-105).

Comparative assessment of crop yields (tn/ha)

Table 6.1

Yangiyul district (actual)	2000	2001	2002	2003
Cucurbits	26.67	14.80	15.47	16.33
Grapes	6.18	7.04	2.36	1.76
Cereals	3.41	3.99	4.81	4.52
Potato	16.50	20.86	19.81	21.78
Kenaf	15.74	14.93	15.30	16.57
Corn	2.74	3.08	3.18	4.01
Maize for silage and green fodder	16.92	22.27	29.20	26.67
Perennial grass of past years for green forage	28.08	22.70	30.08	33.76
Perennial grass of past years for hay	6.81	8.32	10.31	10.90
Perennial grass of current year for green forage	20.99	20.61	27.15	25.54
Perennial grass of current year for hay	11.06	7.38	8.50	9.52
Vegetables	19.08	18.78	20.42	21.06
Annual grass	12.30	14.50	11.90	13.20
Rice	2.73	3.56	4.71	3.27
Fruits	5.37	4.77	5.93	3.15
Cotton	2.37	2.70	1.99	2.05
Fodder roots	17.60	20.00	28.89	25.00

Table 6.2

Yangiyul district (simulation)	2000	2001	2002	2003
Cucurbits	19.20	16.70	16.40	15.90
Grapes	4.55	4.75	4.20	3.90
Cereals	4.10	4.30	4.50	4.90
Potato	18.60	19.10	19.60	19.80
Kenaf	15.20	15.30	15.25	15.60
Corn	3.20	3.40	3.60	3.60
Maize for silage and green fodder	19.10	23.10	25.60	25.30
Perennial grass of past years for green forage	11.20	12.30	11.30	11.80

Perennial grass of past years for hay	7.10	7.30	8.10	8.20
Perennial grass of current year for green forage	9.10	9.30	9.80	10.20
Perennial grass of current year for hay	8.10	8.20	8.60	8.50
Vegetables	20.40	20.50	21.20	22.40
Annual grass	9.30	11.20	9.40	10.20
Rice	3.20	3.40	4.50	4.30
Fruits	5.20	4.90	5.40	5.30
Cotton	2.66	2.51	2.65	2.65
Fodder roots	22.60	23.40	25.30	24.20

Relative deviations between simulated and actual crop yields

Table 6.3

Yangiyul district (deviations)	2000	2001	2002	2003	Mean for 4 years	Mean square
Cucurbits	-0.33	0.12	0.06	-0.03	-0.04	0.34
Grapes	-0.30	-0.39	0.56	0.76	0.16	1.02
Cereals	0.18	0.07	-0.07	0.08	0.07	0.18
Potato	0.12	-0.09	-0.01	-0.10	-0.02	0.17
Kenaf	-0.03	0.02	0.00	-0.06	-0.02	0.06
Corn	0.15	0.10	0.12	-0.11	0.07	0.21
Maize for silage and green fodder	0.12	0.04	-0.13	-0.05	-0.01	0.19
Perennial grass of past years for green forage	-0.86	-0.59	-0.91	-0.96	-0.83	0.28
Perennial grass of past years for hay	0.04	-0.13	-0.24	-0.28	-0.15	0.25
Perennial grass of current year for green forage	-0.79	-0.76	-0.94	-0.86	-0.84	0.14
Perennial grass of current year for hay	-0.31	0.11	0.01	-0.11	-0.08	0.31
Vegetables	0.07	0.09	0.04	0.06	0.06	0.04
Annual grass	-0.28	-0.26	-0.23	-0.26	-0.26	0.03
Rice	0.16	-0.05	-0.05	0.27	0.08	0.27
Fruits	-0.03	0.03	-0.09	0.51	0.10	0.48
Cotton	0.11	-0.07	0.28	0.26	0.15	0.28
Fodder roots	0.25	0.16	-0.13	-0.03	0.06	0.30

As Table 6.3 shows, the maximum deviation of simulated data from actual one is observed for crops (grapes, fruits) subjected to climate stresses (sudden froze in spring, abundant precipitation) not included in basic equations. During further model improvement, the authors would try to overcome these shortcomings.

6.4 Validation of the modeling set.

All simulations by the described models were made for a whole series of last years but their validation for future scenario simulations was made on the basis of comparison with 2000-2003. These years are base years for simulation of future scenarios. Table 6.4 shows comparison of simulated economic indicators with statistical data [15].

Comparison of simulated and statistical economic indicators for agriculture

Table 6.4

Tashkent province (2003)	Simulation			Statistics		
	Gross volume ($)	Profit ($)	GDP ($)	Gross volume ($)	Profit ($)	GDP ($)

Irrigated area	165 352 840	27 640 842	154 492 972	161 537 800	27 045 000	*
Dry land	2 588 561	1 178 278	2 306 504	2 427 600	927 800	
Homestead plots	58 717 113	15 627 113	15 627 113	58 402 000	17 830 900	
TOTAL for crop production	226 658 514	44 446 232	172 426 589	222 367 400	45 803 700	
TOTAL for livestock-breeding	231 510 349	49 960 719	111 124 967	233 753 500	53 559 600	
Grand TOTAL for agriculture	458 168 863	94 406 951	283 551 556	456 120 900	99 363 300	276 590 000

* Official reports give only statistical data on GDP for agriculture in general, without division into separate areas.

As a result of cumulative estimation of major indicators of sub-basin development within Tashkent province, we derived cost indicators of gross production volume and GDP per main economic sectors and compared them with official macro-economic indicators (Table 6.5).

Table 6.5

	Industry					AgroIndustry			
	Simulation		Statistics			Simulation		Statistics	
	GV	GDP	GV	GDP		GV	GDP	GV	GDP
	mln.$	mln.$	mln.$	mln.$		mln.$	mln.$	mln.$	mln.$
1995	1327.32	278.74	1285.01	269.85		508.06	177.82	224.99	78.75
2000	980.20	205.84	998.43	209.67		288.04	100.81	313.57	109.75
2001	851.73	178.86	847.08	177.89		278.72	97.55	288.42	100.95
2002	702.87	147.60	716.53	150.47		273.90	95.86	263.67	92.29
2003	712.51	149.63	718.66	150.92		271.20	94.92	260.44	91.15

	Agriculture					Service			
	Simulation		Statistics			Simulation		Statistics	
	GV	GDP	GV	GDP		GV	GDP	GV	GDP
	mln.$	mln.$	mln.$	mln.$		mln.$	mln.$	mln.$	mln.$
1995	488.29	361.34	430.40	318.50		718.11	617.57	530.36	456.11
2000	458.45	339.25	403.88	298.87		514.85	442.77	568.81	489.18
2001	455.79	337.28	464.06	343.40		525.86	452.24	480.13	412.91
2002	454.59	336.40	481.23	356.11		549.06	472.19	423.86	364.52
2003	454.24	336.13	486.04	359.67		579.51	498.38	420.00	361.20

	Region			
	Simulation		Statistics	
	GV	GDP	GV	GDP
	mln.$	mln.$	mln.$	mln.$
1995	3041.78	1435.47	2470.76	1123.20
2000	2241.54	1088.68	2284.69	1107.47
2001	2112.09	1065.93	2079.68	1035.14
2002	1980.42	1052.06	1885.29	963.39
2003	2017.46	1079.06	1885.14	962.94

7 CONCLUSION

1. The developed model set "Socio-economic model" is dedicated to estimate major indicators of sub-basin's socio-economic development under conditions of transition economy and limited statistical data and based on a need to evaluate parameters of future water development scenarios. The proposed systems of models and methodology allows using combination of available aggregated trends in the scale of the whole zone and its individual parts together with indicators obtained from selective detailed research in representative objects and from field studies conducted by the authors previously.
2. The agricultural block is developed in more details and represents dynamics of agriculture oriented to major water consumer in the region – irrigated agriculture – and which is the core of future sub-basin's development scenarios. The models of agricultural block were validated by comparing simulated and actual crop yield data for the period from 2000 to 2004. Validation showed quite good fitting, despite the fact that this period includes both dry and humid years. Moreover, besides validation against crop yields, the agricultural block was tested in general for representation of economic indicators, including: gross output, costs, profit, GDP of agriculture depending on water availability and investments. Despite the uncertainty of a great number of indicators, such as inflation, subsidies, impact of farm size and changes in ownership forms, the results of comparison with actual data may be considered as satisfactory for future planning.
3. The socio-economic block is developed regarding dynamics of three other economic sectors as well. There is no such analogue in similar models recommended within the framework of developed projects of water development scenarios. Though available trends in studied sub-basin are characterized by quite poor explainable fluctuations, we managed to simulate and validate, as well as to aggregate all socio-economic indicators into inter-linked complex for future planning.
4. In finalizing project work, it is necessary to make some clarifications regarding methodology and indicators themselves, particularly in part of agricultural product price dynamics and production costs, changed norms of depreciation charges under transformation of ownership forms and a number of other important indicators characterizing the effect of water-related development on general welfare in the region. Here, effect of agricultural production growth on GDP generation in agro-industry and services sector should be considered as well.

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9 ANNEX

9.1 Inputs in crop production

Table 9.1

	Roots	*Kenaf*	*Alfalfa*
Mechanical and manual work ($/ha).			
Autumn-winter operations	23 - 29	27 – 32	0
Pre-plant operations	18 - 23	20 – 25	10 - 11
Seeding	15 - 20	15 – 22	8 - 9
Plant treatment	35 - 37	45 – 53	50 - 55
Harvesting	70 - 80	70 – 80	70 - 75
Sub-total	161 - 189	177 - 212	138 - 150
Input costs ($/ha).			
N	30 - 35	39 - 46	20 - 25
P	18 - 23	30 - 35	22 - 27
K	20 - 22	20 - 23	10 - 11
Seeds	30 - 35	35 - 40	40 - 45
Chemical protection	20 - 23	20 - 30	10 - 15
Transport	35 - 40	20 - 25	30 - 35
Sub-total	153 - 178	164 - 199	132 - 158
Total	314 - 367	341 - 411	270 - 308

Table 9.2

	Cotton	*Cereals*	*Maize*
Mechanical and manual work ($/ha).			
Autumn-winter operations	25 - 30	15 - 16	25 – 30
Pre-plant operations	20 - 25	18 - 21	20 – 25
Seeding	15 - 20	12 - 15	10 – 12
Plant treatment	50 - 60	25 - 28	42 – 47
Harvesting	70 - 75	65 - 70	65 – 70
Sub-total	180 - 210	135 - 150	162 – 184
Input costs ($/ha).			
N	45 - 50	25 - 30	40 – 45
P	32 - 35	22 - 27	28 – 32
K	15 - 20	10 - 12	10 – 15
Seeds	30 - 35	30 - 35	21 – 25
Chemical protection	20 - 25	12 - 25	15 – 20

Transport	20 - 23	15 - 19	10 – 15
Sub-total	162 - 188	144 - 148	124 – 152
Total	342 - 398	279 - 298	286 – 336

Table 9.3

	Rice	***Potato***	***Vegetables***
Mechanical and manual work ($/ha).			
Autumn-winter operations			
Pre-plant operations	23 - 25	13 - 16	12 - 15
Seeding	20 - 25	23 - 27	20 - 25
Plant treatment	50 - 55	60 - 65	45 - 50
Harvesting	63 - 70	75 - 80	70 - 80
Sub-total	156 - 175	171 - 188	147 - 170
Input costs ($/ha).			
N	38 - 42	25 - 30	28 - 35
P	35 - 38	23 - 25	25 - 30
K	10 - 15	12 - 15	12 - 18
Seeds	80 - 100	50 - 55	25 - 30
Chemical protection	18 - 30	25 - 30	20 - 25
Transport	17 - 20	25 - 35	20 - 30
Sub-total	198 - 245	160 - 190	130 - 168
Total	354 - 420	331 - 378	277 - 338

Table 9.4

	Cucurbits	***Fruits***	***Grapes***
Mechanical and manual work ($/ha).			
Autumn-winter operations		10	15
Pre-plant operations	15 - 18	20	20
Seeding	18 - 20		
Plant treatment	50 - 52	80 - 90	85 - 100
Harvesting	65 - 70	125 - 150	130 - 160
Sub-total	148 - 160	235 - 270	250 - 295
Input costs ($/ha).			
N	25 - 30	30 - 35	30 - 35
P	20 - 25	30 - 35	25 - 30
K	10 - 12	10 - 15	10 - 15
Seeds	15 - 20	14	15
Chemical protection	15 - 25	30 - 50	30 - 50
Transport	20 - 30	30 - 40	35 - 45
Sub-total	105 - 142	144 - 189	145 - 190
Total	253 - 302	379 - 459	395 - 485

9.2 Purchasing prices of agricultural products ($/t) and their sale (%).

Table 9.5

Культура	2000		2001		2002	
	Purchase by government	Market	Purchase by government	Purchase by government	Market	Purchase by government
Raw cotton	216.7		204.7		159.3	
Cereals	121.9	127.5	93.0	110.7	85.8	93.8

Corn	140.9	170.2	125.4	155.0	106.1	112.8
Rice	247.7	290.6	216.0	224.3	189.4	210.3
Potato	130.4	190.8	133.5	184.9	135.8	194.3
Vegetables	51.8	74.3	120.6	164.1	36.3	42.6
Cucurbits		90.3		185.3		53.0
Fruits	60.3	74.8	58.6	70.2	54.5	70.4
Grapes	117.9	203.5	108.0	170.6	91.7	140.9
Fodder beet	23.0	33.8	21.7	31.4	20.6	31.0
Kenaf	29.6	33.4	27.6	29.8	24.0	35.5
Alfalfa (hay)	41.3	60.2	42.4	61.3	44.0	62.7
Alfalfa (green fodder)	11.7	17.5	11.8	16.1	12.6	17.1
Maize (silage)	17.0	19.3	16.0	18.7	16.9	19.3
Maize (green fodder)	17.0	19.3	16.0	18.7	16.9	19.3
Vegetables (tomato)	75.2	130.9	81.6	159.2	80.3	140.7

Table 9.5 (continued)

Культура	2003		Sale, % 2003	
	Purchase by government	Market	Purchase by government	Market
Raw cotton	200.0		100.0	0.0
Cereals	69.0	81.3	70.0	30.0
Corn	70.0	80.6	10.0	90.0
Rice	170.0	200.0	60.0	40.0
Potato	130.0	150.0	5.0	95.0
Vegetables	46.0	60.5	30.0	70.0
Бахчи		21.5	0.0	100.0
Cucurbits	58.0	76.8	20.0	80.0
Fruits	110.0	130.0	20.0	80.0
Grapes	25.0	30.6	25.0	75.0
Fodder beet	62.0	93.6	75.0	25.0
Alfalfa (hay)	58.4	71.0	20.0	80.0
Alfalfa (green fodder)	14.9	19.4	30.0	70.0
Maize (silage)	20.7	24.0	80.0	20.0
Maize (green fodder)	20.7	24.0	50.0	50.0
Vegetables (tomato)	77.4	120.0	30.0	70.0

9.3 Effect of nitrogen fertilizer application norms and dates on raw cotton yields under conditions of light sierozem, centner/ha

Table 9.6

Annual fertilizer norm, kg/ha		Nitrogen fertilizer application dates					
N	P	Tillage	Before sowing	2-3 leaves formed	At the beginning of budding	Early flowering	Early fruit formation
-	-	-	-	-	-	-	-
-	150	-	-	-	50	-	-
150	150	-	50	-	50	50	-
200	150	-	100	-	50	50	-
250	175	-	100	50	50	50	-
250	175	-	150	-	50	50	-
250	175	100	-	50	50	50	-
250	250	-	100	50	50	50	-
350	175	-	150	50	50	50	50

350	175	150	50	50	50	50	-
350	250	-	150	50	75	75	-
350	250	-	200	50	50	50	-

Table 9.7

Annual fertilizer norm, kg/ha		Yields per year			Mean for 3 years	
N	P	1971	1972	1973	Yield	Increase
-	-	20.8	22.9	19.5	21.1	-
-	150	21.9	24.5	20.7	22.3	-
150	150	36.6	38.7	37.4	37.6	15.2
200	150	41.3	43.2	39.2	41.2	18.9
250	175	42.6	45.6	43.6	43.9	21.6
250	175	42.9	46.1	41.3	43.4	21.1
250	175	38.9	43.5	40.2	40.9	18.5
250	250	41.6	44.3	41.1	42.3	20.0
350	175	41.0	47.0	44.3	44.2	21.8
350	175	43.0	51.3	48.5	47.6	25.2
350	250	42.2	48.6	45.7	45.5	23.1
350	250	-	47.6	44.3	45.8	23.3

Effect of nutrient elements on raw cotton yields

Table 9.8

Quantity of nitrogen kg/ha	1972			1973			1974		
	Actual density, thousand./ha	Yield, center/ ha	Increase center/ ha	Actual density, thousand./ ha	Yield, center/ ha	Increase center/ ha	Actual density, thousand./ha	Yield, center/ ha	Increase center/ ha
100.0	124.0	27.6	-	88.0	38.9	-	72.8	39.6	-
	260.0	31.2	+ 3.5	308.0	41.3	+ 2.4	310.0	42.6	+ 3.0
	420.0	30.6	+ 3.0	502.0	38.6	- 0.3	377.0	41.7	+ 2.1
200.0	115.0	28.5	-	90.0	39.2	-	77.1	39.8	-
	224.0	32.6	+ 4.1	335.0	42.4	+ 3.2	284.0	43.4	+ 3.6
	415.0	29.5	+ 1.0	495.0	39.1	- 0.1	315.0	42.8	+ 3.0
300.0	125.0	21.9	-	89.2	39.2	-	-	-	-
	241.0	25.2	+ 3.2	352.0	42.2	+ 3.0	-	-	-
	415.0	26.1	+ 4.2	430.0	37.6	- 1.6	-	-	-

Table 9.8 (continued)

Quantity of nitrogen kg/ha	1975			Mean	
	Actual density, thousand./ha	Yield, center/ ha	Increase center/ ha	Yield, center/ ha	Increase center/ ha
100.0	-	-	-	35.3	-
	-	-	-	38.3	+ 3.0
	-	-	-	36.9	+ 1.6

200.0	85.4	38.35	-	36.4	-
	202.0	42.50	4.2	40.5	+ 4.1
	407.0	40.00	+ 2.7	37.8	+ 1.4
300.0	87.5	39.63	-	33.5	-
	260.0	42.90	+ 3.3	36.8	+ 3.3
	420.0	41.22	+ 2.6	35.2	+ 1.7

Effect of nutrient elements on raw cotton yields

Table 9.9

Experiment option	Raw-cotton yield per year, g per plant					
	1969	1970	1971	1972	1973	mean
No fertilizer	52.8	55.8	35.9	25.6	15.3	34.9
N	130.9	110.0	94.3	75.7	39.7	89.7
N P	177.3	123.3	102.2	80.5	80.5	104.1
N P K	150.1	139.7	139.0	106.5	54.6	118.6

Nutrient content (%) in the soil after ploughing up of alfalfa

Table 9.10

Year	Typical sierozem	Light sierozem	Meadow soil
third	1 : 0.9	1 : 1 - 1 : 0.9	1 : 1.25
fourth	1 : 0.9 - 0.8	1 : 0.9 - 0.8	1 : 1 - 1.0
fifth	1 : 0.8 - 0.7	1 : 0.9 - 0.8	1 : 1 - 0.9
sixths	1 : 0.7	1 : 0.8 - 0.7	1 : 0.9 - 0.8
next following years	1 : 0.7 - 0.6	1 : 0.7	1 : 0.8 - 0.9

Data in Tables 9.7 – 9.10 were used for model calibration.

9.4 Temperatures needed for main plant development phases.

Cotton (medium-stapled)

Table. 9.11

Indicator	Development phases				Total
	Vegetative	Budding – flowering	Fruit formation	Maturing	
Number of days	35 – 40	28 -30	55	60	178 -185
Total quantity of temperatures, ^{0}C	590	680	1520	1145	3935
Total effective temperatures, (higher than + 10 ^{0}C)	235	390	970	545	2140

Recommended sowing date –1st -2nd ten-day periods in April.

Cereals (winter)

Table 9.12

Indicator	Development phases				Total
	Vegetative	Ear development and flowering	Yield formation	Maturing	
Number of days	40	35	50	20	230 (of which 80 – 90

					days of winter dormancy)
Total quantity of temperatures, ^{0}C	375	415	883	435	2108
Total effective temperatures, (higher than + 5 ^{0} C)	175	240	633	335	1383

Recommended sowing date – 2nd ten-day period in October.

Maize (corn)

Table 9.13

Indicator	Development phases				Total
	Vegetative	Flowering	Yield formation	Maturing	
Number of days	50	20	30	40	140
Total quantity of temperatures, ^{0}C	823	560	805	938	3126
Total effective temperatures, (higher than + 10 ^{0} C)	323	360	505	538	1726

Recommended sowing date – 1st ten-day period in April.

Rice

Table 9.14

Indicator	Development phases				Total
	Vegetative	Flowering	Yield formation	Maturing	
Number of days	45	35	25	20	125
Total quantity of temperatures, ^{0}C	900	955	630	490	2965
Total effective temperatures, (higher than + 10 ^{0} C)	450	605	380	290	1725

Recommended sowing date – 3rd ten-day period in April.

Cucurbits

Table 9.15

Indicator	Development phases				Total
	Vegetative	Flowering	Yield formation	Maturing	
Number of days	40	25	30	20	115
Total quantity of temperatures, ^{0}C	810	650	775	320	2635

Total effective temperatures, (higher than + 10 ^{0}C)	490	400	475	120	1485

Recommended sowing date – 1st ten-day period in May.

Alfalfa (fodder grass)

Table 9.16

Indicator	Development phases				Total
	Vegetative	Flowering	Yield formation	Maturing	
Number of days	60	15	60	70	205
Total quantity of temperatures, ^{0}C	679	318	1500	1680	4177
Total effective temperatures, (higher than + 10 ^{0}C)	79	168	900	980	2127

Recommended sowing date – 1st ten-day period in March (5 mowing offs during growing season or harvesting as regrows under flowering 25% of plants per sown area)

Grapes

Table 9.17

Indicator	Development phases				Total
	Early vegetation	Flowering	Yield formation	Maturing	
Number of days	55	25	60	40	180
Total quantity of temperatures, ^{0}C	837	576	1625	925	3963
Total effective temperatures, (higher than + 10 ^{0}C)	287	326	1025	525	2163

Fruits

Table 9.18

Indicator	Development phases				Total
	Vegetative	Indicator	Development phases	Total	

Number of days	60	20	60	45	185
Total quantity of temperatures, ^0C	940	520	1650	970	4080
Total effective temperatures, (higher than + 10 ^{0} C)	310	320	1050	520	2230