



PROJECT

Transboundary water management adaptation in the Amudarya basin to climate change uncertainties

Report

2.8.1 Model of planning zone.

Module for calculation of irrigated agriculture output and foodstuff

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1. Research objective and tasks:

- Completing an optimization module for cropping pattern and calculation of foodstuff in PZ
- Programming the optimization module for cropping pattern and calculation of foodstuff in PZ in the General Algebraic Modeling System (GAMS, Version 24) with the possibility to export and import data into MySQL database (based on the existing program developed by SIC ICWC).

2. Results:

2.1. The model for calculation of irrigated agriculture output in PZ developed in GAMS (Version 24.5.6) with the use of MINOS5 solver. Input data: boundary conditions for PZ area, population, boundary conditions for water resources and water consumption (water deficit), and crop data (irrigated acreage, yield). Gross output of crops per ha and person, output losses under water deficit, water and land productivity (in \$ per ha, per m³ of water) are calculated.

2.2 The module for calculation of foodstuff in PZ in GAMS system (Version 24) with the possibility to export and import data into MySQL database (based on the existing program developed by SIC ICWC). Input data: gross output of crops (calculation of irrigated agriculture production) and coefficients to convert the quantity of produced output into foodstuff. Then foodstuff is calculated.

Capabilities: calibration of the model against actual data, carrying out a numerical simulation experiment (based on such scenarios as business as usual, food security and import substitution, and fulfilled export potential), optimization of cropping patterns against the set of target functions, input of boundary conditions (state order –raw cotton, wheat, etc.).

3. Data:

For the simulation experiment, the data will be taken from the database (A.Sorokin, beginning of June) according to the list of input information.

4. Tasks for future work:

The second stage, 2016. **The computer program will be adjusted to incorporate the following: standard list of crops of ASBmm, which includes double-season crops and homestead plots; the extended list of optimization criteria (target functions).** Numerical simulation experiments will be carried out to debug and calibrate the model against the data on the Khorezm planning zone.

The third stage, 2017. The optimization module for cropping pattern will be completed by development scenarios: food security and/or export potential. **Boundary conditions for optimization will be incorporated (water delivery to homestead plots, fulfillment of the state order, etc.).** The required adjustment of the program will be done in the course of work.

Annex 1. Short description of the computer program

Input data of the program include the actual cropping patterns, yield coefficients, feed mass coefficients, and feed conversion ratio.

Gross output of crops is calculated, as well as unit parameters of foodstuff production.

The list of standard crops is given in Annex 2.

$$FactAmountCrops = Fact_Area_Crops * productivity$$

$$SpecificFactAmountCrops = Fact_Area_Crops * productivity / Population$$

$$Calibration_Feed_Unit = FeedUnitCoef * Fact_Area_Crops * productivity * FeedMassCoef * 10000$$

$$Feed_Cal = \sum FeedUnitCoef_feedcrops * Fact_Area * productivity * FeedMass * 10000$$

$$Roughage_Cal = \sum FeedUnitCoef_RoughageCrops * Fact_Area * productivity * FeedMass * 10000$$

For calculation of dairy and meat output, variable coefficients are inputted ($FeedUnitPastureCal$, $PercentFeed$, $PercentRoughage$) to consider non irrigated agriculture and calculated when solving the optimization problem:

$$FeedUnitPastureCal = \sum Calibration_Feed_Unit * PastureCoefCal$$

$$PastureMilkCal = FeedUnitPastureCal * CoefCalibration / (CoefCalibration + 1)$$

$$PastureMeatCal = FeedUnitPastureCal / (CoefCalibration + 1)$$

$$PercentRoughageMeat = Roughage_Cal - Roughage_Cal * PercentRoughage / 100$$

$$PercentFeedMeat = Feed_Cal - PercentFeed * Feed_Cal / 100 + PastureMeatCal$$

$$Pr odMilkCal = MilkUnit * ((TotalRoughage * PercentRoughage / 100 + PercentFeed * TotalFeed / 100) + PastureMilk) / 1000000$$

$$Pr odMeatCal = \sum Pr odMeatByCattle / 1000$$

$$SpecPr odMeatCal = Pr odMeatCal * 1000 / Population$$

$$SpecPr odMilkCal = Pr odMilkCal * 1000 / Population$$

$$DeviationCal = (Pr odMeatCal - FactPr odMeat)^2 + (Pr odMilkCal - FactPr odMilk)^2$$

$$DeviationCal \rightarrow \min$$

Where the following parameters are inputted and permanent:

$Fact_Area_Crops$ - actual distribution of areas under crops

$productivity$ - crop yields

$Population$ - population in a planning zone

$FeedMassCoef$ - coefficient of conversion into feed mass

$Calibration_Feed_Unit$ - quantity of feed mass

And the following parameters are variable and subjected to optimization and then serve as input for the next phase as permanent parameters, where cropping patterns are to be optimized to achieve food security:

$FeedUnitPastureCal$ – quantity of feed unit, including from non-irrigated agriculture

$CoefCalibration$ - coefficient of forage consumption

$PercentFeed$ - coefficient of soft feed consumption, where

$$PercentFeed = 1 - PercentRoughage$$

$PercentRoughage$ - coefficient of roughage consumption

$PastureCoefCal$ - pasture coefficient

Calculations of the first phase:

The following actual data are inputted into the program: distribution of irrigated areas under crops, yields, coefficients of feed mass formation, coefficients of feed unit formation, coefficients of double-season cropping, innovation coefficients (to increase yields and reduce water requirements), as well as actual meat and dairy production. Then optimization of the first phase is carried out against the criterion: minimizing standard

deviation of actual meat and dairy production from estimated one to calibrate variable coefficients that consider non irrigated agriculture (pastures, rain-fed areas).

The next phase of the program:

$$\begin{aligned}
 TotalYield &= Inn_Area * CropArea * Inn_Productivity * productivity \\
 WaterRateByCrop &= Inn_Area * CropArea * Inn_WaterRate * WaterRate \\
 FeedMass &= TotalYield * FeedMassCoef \\
 FeedUnit &= FeedUnitCoef * FeedMass * 10000 \\
 TotalRoughage &= \sum FeedUnit \\
 TotalFeed &= \sum FeedUnit \\
 FeedUnitPasture &= \sum FeedUnit * PastureCoefCal \\
 Area &> \sum CropArea \\
 PastureMilk &= FeedUnitPasture * CoefCalibration / (CoefCalibration + 1) \\
 PastureMeat &= FeedUnitPasture * (CoefCalibration + 1) \\
 PercentRoughageMilk &= TotalRoughage * PercentRoughage / 100 \\
 PercentFeedMilk &= PercentFeed * TotalFeed / 100 \\
 ProdMilk &= MilkUnit * ((TotalRoughage * PercentRoughage / 100 + PercentFeed * TotalFeed / 100) + PastureMilk) / 1000000 \\
 PercentRoughageMeat &= TotalRoughage - TotalRoughage * PercentRoughage / 100 \\
 PercentFeedMeat &= TotalFeed - PercentFeed * TotalFeed / 100 + PastureMeat \\
 ProdCrop &= CropArea * productivity \\
 SpecProdCrop &= ProdCrop * 1000 / Population \\
 Amount_Water &> \sum WaterRateByCrop \\
 DeviationFromStd &= \sum (SpecProdCrop - stdCrop)^2 \\
 DeviationFromStd &\rightarrow \min
 \end{aligned}$$

Where:

- *TotalYield* – gross output of crop (*input parameter*)
- *Inn_Area* – area where innovations are applied (*input parameter*)
- *CropArea* – area under crop (*input parameter*)
- *Inn_Productivity* – innovation coefficient increasing crop yield (*input parameter*)
- *Productivity* – coefficient of crop yield (*input parameter*)
- *WaterRateByCrop* – crop water requirements (*input parameter*)
- *Inn_WaterRate* – coefficient of reduction of crop water requirements through innovations (*input parameter*)
- *WaterRate* – water use (*input parameter*)
- *FeedMass* – feed mass (*input parameter*)
- *FeedMassCoef* – feed mass coefficient (*input parameter*)
- *FeedUnit* – feed units (*input parameter*)
- *FeedUnitCoef* – coefficient for conversion of feed mass into feed unit (*input parameter*)
- *TotalRoughage* – total roughage calculated by crop – cotton, maize, rice and wheat (*output parameter*)
- *TotalFeed* – total soft feed calculated by crop – forage, vegetables (*output parameter*)
- *FeedUnitPasture* – feedstuff from pasture (*output parameter*)
- *PastureCoefCal* – coefficient to consider pastures (*coefficient derived in the first phase*)

- *PastureMilk* – calculated dairy output, including pastures – feed from non-irrigated areas (*output parameter*)
- *CoefCalibration* – calibration coefficient for more accurate calculation (*coefficient derived in the first phase*)
- *PastureMeat* – calculated meat output, including pastures – feed from non-irrigated areas (*output parameter*)
- *PercentRoughageMilk* – percentage of roughage used for feeding in dairy production (*output parameter*)
- *PercentRoughage* – percentage of roughage use (*calibration factor derived in the first phase*)
- *PercentFeedMilk* – percentage of soft feed used for feeding in dairy production (*output parameter*)
- *PercentFeed* – percentage of soft feed use (*calibration coefficient derived in the first phase*)
- *ProdMilk* – dairy production, tones (*output parameter*)
- *MilkUnit* – coefficient for conversion of milk unit into kilograms (*output parameter*)
- *PercentRoughageMeat* – percentage of roughage used for cattle feeding (*calibration coefficient derived in the first phase*)
- *PercentFeedMeat* – percentage of soft feed used for cattle feeding (*calibration coefficient derived in the first phase*)
- *ProdCrop* – Crop production, tones (*output parameter*)
- *SpecProdCrop* – Unit food production, person/kg (*output parameter*)
- *Amount_Water* – Available water, m³ (*input parameter*)
- *WaterRateByCrop* – crop water requirements (*input parameter*)
- *DeviationFromStd* – Standard deviation of produced output from consumer basket in Central Asian region (*output parameter*)

std_crop – Consumer basket in Central Asian region (*input parameter*)

In this phase, the following data are inputted into the program: yield data, coefficients of feed mass formation, coefficients of feed unit formation, coefficients of double-season cropping, innovation coefficients (to increase yield and reduce water requirements), coefficients of agricultural output processing into foodstuff, number of cattle stock, population and limits on area (net) and irrigation water; the program also receives calibration coefficients (pasture coefficients to calculate feed from non-irrigated agriculture and coefficients of feed division by meat and dairy production) derived in the first phase to correct calculation of foodstuff. The areas under homestead plots and crops (from the list of 9 standard crops) are not considered in the optimization of cropping patterns.

It should be mentioned additionally that in this phase it is possible to fix maximal and minimal areas under a particular crop. In the third phase, the rest of PZ area and unused water limit are used to get the maximum added value:

$$\left\{ \begin{array}{l}
 \text{IncomeByCrop} = \text{CropArea} * \text{productivity} * \text{Cost} \\
 \text{ExpensesByCrop} = \text{CropArea} * \text{Coef_Expenses} \\
 \text{ProfitByCrop} = \text{IncomeByCrop} - \text{ExpensesByCrop} \\
 \text{WageByCrop} = \text{CropArea} * \text{Wages} / 100 \\
 \text{TaxByCrop} = \text{CropArea} * \text{Tax} / 100; \\
 \text{AddedTaxByCrop} = \text{ProfitByCrop} * \text{Conversion} + \text{WageByCrop} + \text{TaxByCrop} + \text{ProfitByCrop} \\
 \text{AddedTaxByCrop} \rightarrow \max
 \end{array} \right.$$

Annex 2

List of crops in the ASBmm (9 main crops)

Symbol	Name	Notes
C = { }	Crops	Elements of "Crops" file
cot	Cotton	Cotton
whe	Wheat	Wheat
ric	Rice	Rice
mai	Maize	Maize for grain
veg	Vegetables	potato, tomato, root crop, legumes, and cucurbits
orc	Orchards	Orchard and grapes
for	Forage	corn for silage, alfalfa
oth	Other	Other grain and industrial crop – oil crop, sugar beet, tobacco, etc.
hom	Homestead	Crops grown in homestead plots
	Double crops	Double-season crops; not included in the list of 9 crops but considered through multiplying factors for: a) vegetables (carrot, mung bean, legumes, radish, etc.), b) forage crops and c) rice. They are sown after harvesting of wheat.