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Introducing ecosystem service evaluation indicators in monitoring of irrigated agriculture in Uzbekistan (within the project ELD Central Asia)

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ABSTRACT

For regular analysis and tracking of changes in the valuation of ecosystem services in irrigated agriculture, indicators and data sources included in a unified system of statistical services in rural areas are needed. In general, the development and introduction of such indicators and data will help to guide monitoring ecosystem services in areas such as cotton and grain farming, the main agricultural crops in irrigated agriculture of Uzbekistan.

Currently, almost all information is obtained through interviews, which is very labor intensive and covers a rather small radius of the population and areas involved in agricultural activities. Therefore, the development of new indicators for statistical reporting systems will improve the ability of ecosystem services' value estimates at the level of decision-making.

Keywords: Economic Assessment of Ecosystem Services, Bio-agriculture, Irrigated Agriculture, Agricultural Economics

PAPER

1. Introduction

Agriculture is one of the priority areas of national economy. Uzbekistan has favourable climatic conditions for production of various agricultural, including industrial crops. A significant portion of sown areas and almost all land under technical crops are irrigated lands served by a large public irrigation system.

Diminishing soil fertility in agriculture is one of the issues that need to be tackled. The content of humus in the soil decreases. Thus, in the study area, about 76 % of arable areas have content below 1 %, 22 % contain from 1 to 2% organic matter, and the remaining about 1% of irrigated arable land contains from 2 to 3% organic matter.

Improvement of soil structure can be achieved by rational combination (rotation) of crops. It is necessary to expand the area under crops and trees allowing the accumulation of nutrients in the soil. A rational choice of crops can reduce the amount of mineral fertilizers and various other chemicals, contaminating land and water.

Some international studies show, that average GHG emissions from traditional cotton cultivation can be 3,236kg CO e/ha and 1.5 kg CO e/kg of seed cotton produced. For a detailed analysis of carbon emissions from cotton cultivation, a further study is needed, because farmers and local authorities do not collect such data[1].

In accordance to some literature[2], the soil organic carbon stock (SOC) under irrigated cotton varied from 15 to 43 Mg C ha^{-1}. Perennial crops generally have the widest range of SOC stock as from 11 to 241 Mg C ha^{-1}, similar to a land use as pasture type. Currently the area under orchards and vineyards in the surveyed farms is only around 1.5 %. Absorption of carbon dioxide by tree planting in the surveyed farms approximately amounted to only 35 m3 per year. In the economic program of socio-economic development of the country in 2016, the President of Uzbekistan stressed the need to reduce by 2020 the volume of procurement of cotton to 350 thousand tons. The result, on released cotton plantations will be grown vegetables, potato, fodder, oilseeds and other crops, gardens and vineyards[3].

The traditional varieties of crops (cotton and wheat), subsequent reduction of productivity of

[1] Sumit Roy, Murli Dhar, P Vamshi Krishna, Rebecca May. Cutting cotton carbon emissions - Finding from Warangal, India.
[2] S.M.F. Rabbi and others. Climate and soil properties limit the positive effects of land use reversion on carbon storage in Eastern Australia.
[3] http://uza.uz/ru/business/agrarnaya-sfera-vesomye-tempy-rosta-25-01-2016?ELEMENT_CODE=agrarnaya-sfera-vesomye-tempy-rosta-25-01-2016&SECTION_CODE=business&print=Y.

irrigated areas, and the orientation of farmers to maximize harvest rather than economic benefits of the production function (not examined) require constant and increasing amounts of mineral fertilizers. This process leads to the subsidence of many harmful substances in soil and water, which directly affects the living organisms in the soil. Useful insects (entomophages, etc.) are spreading as a consequence of biological plant protection on irrigated fields. Despite this, use of the land under cotton has consequences such as the extinction of previous organisms and their habitat, staying birds, and various small animals.

Some traditional methods often harm land resources, at the same time causing damage to the environment. So, the burning of straw per hectare leads to emissions of 500 g of nitrogen oxide and 380 g of hydrocarbon, 3 kg of ash, 20 kg exhaust and carbon gases, which leads to the spread of various diseases. This process disrupts the structure of the soil, which leads to increased soil erosion and declining yields. In addition, entomophages and useful creeping animals die, local plants around the cereal fields are damaged and disappearing.

There are only few statistical materials indicating an influence of agricultural production systems on the environment. Statistical data almost correspond to the set of indicators that are applicable to centrally planned management of agriculture. There are indicators of production volumes, production costs of agricultural products. They tend to give information about the implementation of plans, but do not express the analytic capacity to maintain the conditions for sustainable economic and environmental sustainability of land and water use.

Maintaining the humus balance, the volume relations of plants with nutrient properties of the soil or organic matter, uptake and release of carbon, the prevention of various types of land degradation and others need to be considered as indicators of statistical information at the district level. The basis for the economic calculations is the fact that any economic effect from the use of land in agriculture must maintain the natural fertility of the soil. For this we use and propose indicators of crop rotations in the study area. Cotton cultivation is one of main form of agricultural production in the study area, as well as in Uzbekistan. The main question is how the farmers can conduct the proposed agricultural production in an economically advantageous way, will they change the structure of production taking into account conservation of natural resources?

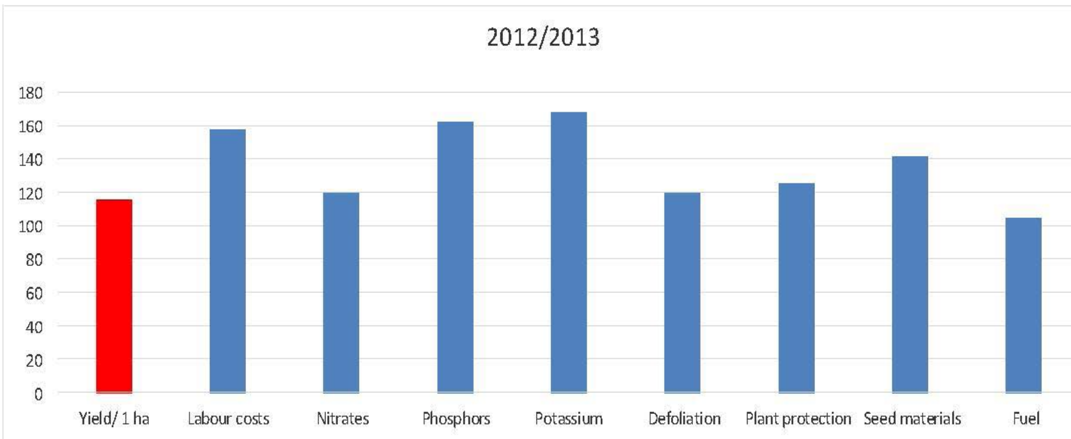
2. Cotton cultivation as a traditional form of land use

In the study of irrigated agriculture, the main products obtained from the interaction with ecosystem services include food, fuel and fibre, the nutrients for their growing. In addition, thematic area focuses on supporting ecosystem services - formation and soil conservation, supporting habitat, air purification, carbon sequestration, allocation of water resources, and cultural – i.e. creating areas for recreation and aesthetic values.

The analysis of the researched farms shows that yields tend to decrease. The yield increase is achieved due to the disproportionate increase of the costs of various production factors. So, when considering years with increasing yields (2013, Figure 1), it is clear that in comparison with 2012 the increase in yield of raw cotton per hectare was accompanied by a high increase in almost all factors of production except fuel.

This aspect clearly indicates a decline in the value of land, as part of the ecosystem, which is the

Figure 1 – Increase of production factors volume comparing to the cotton yield growth



Source: calculated by author based on survey data.

main economic factor in the context of irrigated agriculture. Considering ecosystem services, it directly reflects the provision of nutrients for the production of products from cotton cultivation tends to decrease. Therefore, the main objective of changing the situation, in our opinion, is the change or improvement of the crop rotation system adopted in local conditions.

It should be noted that the demand for by-products from cotton production increases. For example, cotton stalks can be used as raw material for production of furniture and other composite materials. On the other hand, the eventual liberalization of the domestic cotton market may increase the prices of raw cotton. Given the fact that changes also occur in the prices of production factors, it can be assumed that the optimization of production will lead to attractiveness of this type of irrigated agriculture. For a long period, this process will increase the load on land resources, requiring revision of land use from the point of view of crop rotation and reproduction of natural soil fertility.

Table 1 – Total volume of income generation from raw cotton growing, average per farm

	2012	2013	2014
Yield, t	198.4	222	151.2
Area, ha	62	60	56
Total revenue, thousand UZS	167466	206223	158609
Total expenditures, thousand UZS	158573	198519,2	149744
Income, loss (+,-), thousand UZS	8892	7703	8865
Profitability, %	5,6	3,9	5,9
Additional value, thousand UZS	9210	11343	8732
Real total revenue, thousand UZS	176676	217566	167341
Real Income, loss (+,-), thousand UZS	18103	19047	17597
Real profitability, %	11	10	12

Source: by author based on survey data

Since cotton is the raw material base for other industrial forms of production, it is necessary to consider what may occur by outflow of resources from these industries in cotton growing. For example, from raw cotton we can receive about 33 % of the weight in the form of fiber, about 54 % as oil and fodder, and the rest as lint. Changes in the demand for such related products directly affect the degree of attractiveness of cotton production. In addition, it is necessary to take into account the price of cotton fibre on international markets. Changes in these areas consequently can cause an increase of investments in the sector of crop production. Thus, it may lead to further overuse of soil, due to the application of a larger amount of mineral fertilizers, more intensive use of agricultural machinery, etc. As a result, the natural fertility in the long term will continue to decline. For a more detailed analysis, alternative uses in other forms of irrigated agriculture are necessary to be considered.

3. Economic and environmental sustainability of traditional cotton production

Although in the study area stubbing of cotton stalks is not as widespread as in the southern and western regions of Uzbekistan, the tendency of stalks cutting for fuel increases. This factor currently is constrained due to the sufficient gas supply. In many other areas remote from the capital, the gas supply is less. Consequently, all of the cotton stalks are removed. This contributes to a significant decrease in the proportion of organic matter, which naturally would be returned to the soil.

The value of cotton stalks can be also estimated in accordance to possibility of obtaining heat energy. According to some calculations[4], 1 kg dry weight of cotton stalks gives energy in about 15 mega joules. So 1 t dry mass of stalks can be equated to the energy obtained from approximately 0.3 t of diesel fuel. Thus, the value of production of raw cotton may be too attractive to refuse it as a production form leading to intense land degradation. Limiting factor is the increased supply of this raw material, especially in the seasonal section. Taking into account local conditions for the calculations, we choose cost rates that were obtained during surveys in the study area. Using data of fertilizers' cost obtained on the studied farms and comparing required amount of their additional contribution due to a withdrawal of organic mass, we can calculate the cost of losses from the collection of cotton stalks by the field after harvest (table 2).

The cotton production takes up to 3 t of organic mass from one ha under collection of cotton stalks for fuel and other needs. In order to cover the loss of nutrients that are not reproduced due to the withdrawal of this organic mass, farmer needs to apply about 14 t of organic fertilizer (table 2). Application of organic fertilizer restores the contents of nitrogen, phosphorus and potassium in the soil. Under normal conditions, 1 t of organic fertilizer covers 5 kg of nitrogen,

[4] T.A. Gemtosa, Th. Tsiricoglou. Harvesting of cotton residue for energy production.

Table 2 – Indicators of calculating cost of mineral fertilizers for reproduction of nutrients in the soil for the permanent cotton production[5]

Factors	Quantity	Value, UZSs		
The withdrawal of organic matter by cultivation of cotton (t)	3	2012	2013	2014
Reimbursement (organic fert., t)	14			
Nitrogen (kg)	68	76834	82602	109084
Phosphorus (kg)	20	23050	24781	32725
Potassium (kg)	55	61075	69404	76364
Total		160959	176787	218173

Source: by author based on survey data

4 kg of phosphorus and 1.5 kg of potassium. To resume the production of raw cotton, equivalent to the previous year, the farmer must purchase the necessary amount of mineral fertilizers with these nutrients.

Based on the table of profitability of growing cotton on the studied farms, the number of required types of fertilizers is multiplied by the price of their purchase. The result is the amount of money the farmer has to spend for the reproduction of substances that are lost due to the loss of humus in the soil. Comparing these values with the income received by the farmer from the sale (withdrawal) cotton stalks from the field, we can see economic loss from such kind of management (table 3). This example shows the economic feasibility of natural reproduction of the soil organic structure in studied conditions.

Table 3 – lEstimated loss from the sale of the cotton stalks for fuel, UZS/ha

Values	2012	2013	2014
Income from the sale of the cotton stalks	148,544	189,0515	155,925
Acquisition cost of NPP (expenses)	160,959	176,787	218,173
Win +/Loss -	-12,415	12,2645	-62,248

Source: by author based on survey data

4 Possibility of optimization in crop rotation

An alternative option for irrigation farming with preservation of the humus balance and economic utility of crop cultivation forms is the possibility of changing crop rotations. An expansion of the area under cultivation of alfalfa can be taken as an example to calculate an alternative scenario. Currently about 3 % of agricultural land on the studied farms is planted by alfalfa , and about 8 % in comparison with the area under the raw cotton cultivation. The proposed alternative aims at a combination within the rotation of alfalfa and cotton cultivations. For example, the calculation is based on maintaining a zero balance of humus as two years of alfalfa and three years of cotton cultivation.

For initial assessment of economic benefits from the preservation of humus balance in soil, initially we compared the cultivation of alfalfa and cotton from the point of view of their profitability in combination of crop rotation, which retains humus balance within a certain time. Calculations show that the production of alfalfa while maintaining the humus balance brings significant economic benefit compared with cotton (table 4). Its value for the study area is more than 80 %. The production of one crop - cotton in this situation brings in annual revenues of approximately 315 thousand UZSs per ha. On the other hand, lack of alfalfa in the crop rotation for the farm brings the loss of up to 255 thousand UZSs per ha annually. Thus, the farmer would be interested in the use of crop rotation including cotton and alfalfa.

The calculations were based on the revenue generated from the cultivation of cotton with the removal of residues from the field. If you eliminate this indicator, the results can change in favour of cotton. However, the income from growing alfalfa is more profitable form of agricultural production, because the livestock sector in the Metropolitan area is developing intensively and farmers can directly sell alfalfa to livestock producers. But cotton production traditionally will remain as a main form of irrigated agriculture in Uzbekistan. It seems it can be reduced to a certain scale, if it is justified from the point of view of maintaining sustainable land productivity. On the other hand, the government will go easier on the sown areas under cotton, if the productivity of land will increase (score of bonitet). The vacated land will be used for agricultural crops with great potential to sustain ecosystem services and biodiversity through soil improvement. For this purpose, it is expedient to further and more detailed study from the point of view of biological and ecological analysis.

[5] Nazarkulov U. (2003) Transformation of agriculture in Uzbekistan and restructuring issues of farm enterprises.

Table 4 – Economic benefit from growing alfalfa compared with cotton (2014)

Production form	Withdrawal/depositing of organic mass, t	Number of rotation years	Gross Margine, UZSs	Income value for 1 year, UZSs*
Cotton cultivation	-4,2	6	314225	314225
Alfalfa cultivation	6,7	4	854000	569333
Difference/benefits of crop rotation				-255108

** excluding the NPV and the discount rate.*

Source: by author based on survey data

At the moment, we mostly use economic interpretation, trying to assess the further course of the implementation possibilities of crop rotations. We are talking about the feasibility of maintaining the humus balance. The challenge is to determine whether the crop rotation is favourable from the point of view of factors as nutrients. On the one hand, it is important to determine how much alfalfa contributes as a supplier of organic mass. On the other hand, it is important to determine the cost of the withdrawal of nutrients by cotton cultivation. It is important to determine the ratio of economic benefits from the factors nutrients such as NPP (Nitrogen, Phosphorus, and Potassium) excluding the impact of the cost of other factors.

Table 5 – Assessment of the value of crop rotation (pictures 2014)

Organic matter, t/ha	6,7	-4,2
Organic fertilizer, t	30,5	-19,1
Nitrogen, kg	152	-95
Phosphorus, kg	46	-29
Potassium, kg	122	-76
The cost of organics in the rotation, UZSs	519230	-325488
The value of land from crop rotation of alfalfa, UZSs	193 743	

Source: by author based on survey data

Calculations show that a farmer will seek to increase the proportion of alfalfa in rotation with cotton. If we take the ratio of cotton to alfalfa as 6 to 4, we can assume that 12 years is the minimum period in which the whole land area may be used under alfalfa 4 years and under cotton 6 years. Calculations of total revenue from use of land under the cotton crop rotation with alfalfa in contrast to the use only under the cotton show that in the first embodiment, the farm receives economic benefit in almost 59 % higher (table 6). 32 % of this additional income in this case is obtained by changing the cost structure of nutrients in the soil.

Table 6 – The yield of farms from the change in crop rotation (the estimated area of 56 ha)

Form of crop rotation	Income**, thousand UZSs
Income from growing only cotton	99528
Income from combination of cotton and alfalfa *	167913
Income from the benefits of preserving the humus balance	53330

** in the ratio of 6 years cotton and 4 years of wheat for 12 years.*

*** for 12 years with a discount rate of 18% per annum.*

Source: by author based on survey data

5. Extension of tree plantations as an alternative scenario for the provision of ecosystem services

Following the alleged alternative option for creating a favourable environment from the point of view of ecosystem services proposes testing approaches to the development of agro forestry. One of the important directions is the creation or renewal of the forest belts around and on the territory of cotton fields. Surveys have revealed that in the past, this issue has received considerable attention at the state level, various programs were implemented to create windbreaks.

By combining these two forms of agricultural production, cotton yield would increase. This is an additional incentive to use this approach, because land allotment from cotton farming is a difficult process. Besides, it is necessary to take into account the risk of long-term investments, which farmers can accept only for a smaller area. Therefore, we can focus on the forestland approximately 3% of arable land currently used under cotton. The studied farms in 2014 used for cotton cultivation an average of 56 ha per farm. Thus, about 2 ha, the farmer can use under planting of trees. In this case, we focus on poplar (table 7). To calculate the net present value we use a discount factor of 1.18.

Table 7 – Calculation results of poplar growing on the cotton fields (the period of poplar maturity expected as 9 years). UZS

	2105	NPV, 2024
Income from 2 ha of planted poplar	-900000	8335862
Income from yield increase by 15%, 54 ha	22941630	116487635
The income from cotton cultivation, 56 ha	17596600	89347894
Income volume by poplar growing on the cotton fields		124823497
The benefit to the farmer, %		39,7

Source: by author based on survey data

The sequence of calculations from the farmer's point of view is carried out in accordance with the definition of benefit from the value of the timber that he can sell in 9 years (8.3 million UZSs), and the additional revenue from raw cotton production (116.5 million UZSs). This is obtained because of higher yields through the establishment of forest plantations. Thus, the net present value of revenue from this combination of both production forms is obtained in an amount of 124.8 million UZSs. If we take into account the production of only cotton, net present value of revenue over 10 years would have been approximately 89.3 million UZSs. Therefore, this alternative would bring the farmer an income that would exceed the traditional income at nearly 40 %. In addition, the risk is quite low due to minimum consumption of territory, severed from the main form of agricultural production.

6. Conclusions

- by retaining cotton residues on the field, the farmers have an opportunity to generate additional income from cotton cultivation. In practice, farmers are not aware of the usefulness of this approach, which requires research and awareness of farmers cultivating cotton;

- the remains of the cotton in the field also contribute to the living conditions for insects and microorganisms on the agricultural fields, contributing to the habitat of birds and small animals, such as hares and hedgehogs;

- reducing the amount of applied mineral fertilizers, and keeping residues of cotton on the field in the form of organic matter contribute to reducing emission of carbon dioxide into atmosphere;

- introducing indicators of crop rotation to indicate positive changes of the natural nitrogen amount in the soil. It would allow both to define levels of reducing mineral fertilizers to accumulate more carbon in combination with natural nitrogen in soil;

- indicating of using food base that is created due to the increase of areas under perennial grasses, farmers can get high economic returns through increased livestock production. Thereby reducing the burden on agricultural land, and obtaining organic matter by livestock develop conditions favourable for biodiversity conservation;

- indicating grow of poplar has utility from the standpoint of air purification, wind protection, recreation and aesthetic perception of agricultural landscapes;

- the main feature of growing poplar are main trunks as building material. Thus, there is carbon sequestration, since only part of wood is used as fuel.

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