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ЭКОСИСТЕМЫ: ЭКОЛОГИЯ И ДИНАМИКА
ECOSYSTEMS: ECOLOGY AND DYNAMICS

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СОДЕРЖАНИЕ

Том 3, номер 3, 2019 сентябрь

CONTENTS

Volume 3, Number 3, 2019 September

METHODS OF SUSTENANCE AND RESERVATION OF ECOSYSTEMS AND THEIR COMPONENTS

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ANALYSIS, EVALUATION AND WAYS FOR RATIONAL LAND MANAGEMENT OF NORTH VIETNAM (SUOI SAP CATCHMENT BASIN)[1]

© 2019. V.V. Demidov*, N.M. Shchegolkova*, **, Vo Dai Hai**, Phung Van Khoa***, Bao Huy*****

**M.V. Lomonosov Moscow State University, Faculty of Soil Science*
Russia, 119991, Moscow, Leninskie Gory, 1, Building 12
E-mail: demidov951@yandex.ru, nshegolkova@gmail.com
***Vietnam Academy of Forest Science*
Vietnam, 630000, Hanoi, 06 Nguyen Hong, Buon Ma Thuot, Dak Lak
E-mail: haivodai@gmail.com
****Vietnam State Forestry University*
Vietnam, Hanoi, Xuan Mai, Chuong My. E-mail: khoaphun@mus.edu, baohuy.frem@gmail.com
*****Water Problems Institute of the Russian Academy of Sciences*
Russia, 119333, Moscow, Gubkina Str., 3

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In this article we present the analysis of practical and economical use of the territory of Suoi Sap catchment basin, Son-La province, Vietnam. We used the data of a route survey, performed by the Vietnam National Forestry University, for the assessment. We analyzed the climatic conditions, soil and vegetation resources, and economical use of the territory. The research territory is located in the Northern, mountainous part of Vietnam. It was determined that the slopes of the length from 500 to 2000 m (87%) with steepness from 10° to 40° (90%) prevail in the catchment area. The amount of precipitation (rain) is more than 1750 mm, with most of them falling in summer-autumn (May-September). This leads to the spread of erosion processes, an increase of polluted and degraded lands. In this regard, the organization of rational and efficient use of land should include the creation of optimal conditions for the reproduction and protection of soil fertility, increasing its role in agricultural production. The scientifically based analysis of the impact of natural and other factors on the state of land resources of the catchment area allows us to recommend the use of the most rational and correct criteria and methods of land use in the area. In general, the solution of this problem for similar territories of Vietnam requires the definition of criteria for the ecological and economic efficiency of land use, the analysis of land use, the development of a scientific and methodological approach to the qualitative assessment of land use control in the context of the development of an agrarian economy. WOCAT system has been used in the development of effective watershed land-use technologies.

Keywords: Vietnam, rational lands management, catchment basin, WOCAT.
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Processes related to land degradation are a problem of global importance at present. These processes are especially intensive in South-East Asia, since this region is characterized by rapid population growth, intensive use and over-exploitation of land and water resources.

[1] The research was carried out as part of the project "Scientific and Technological Collaboration of Russia and Association of Southeast Asian Nations in Development and Applying of Innovative Agricultural Technologies to Increase Stability of Agroecological Systems".

In recent years, particular importance is the problem of rational use of land and the Socialist Republic of Vietnam. This is due to the fact that irrational use of agricultural land leads to the decrease in soil fertility, the spread of erosion processes, and an increase the area of polluted and degraded lands. The tasks of increasing the effective use of agricultural areas, taking into account the preservation of their fertility and ecological status in the process of intensification of agricultural production are an integral part of the unified state policy. It is aimed at ensuring the rational use, protection and management of land resources and improving the sustainability of agro-ecosystems (The Ministry ..., 2016).

In this regard, the organization of rational and efficient land use provides for the creation of the most optimal conditions for the reproduction and protection of soil fertility in the agricultural sector, a science-based analysis of the influence of natural and anthropogenic factors on the state of land resources. To solve these problems of rational land use it is necessary to analyze land use, develop scientific and methodological approaches to the qualitative assessment of control over land use in the development of the agricultural economy (Agricultural ..., 2017).

Land resources are the main natural resources of Vietnam. The total natural area of Vietnamese land for 2015 was 33 123 077 hectares. The area of agricultural land is 26 791 580 hectares, which accounts for 81% of the total natural area (The Ministry ..., 2016). The area of agricultural land steadily increased (1994-2015) from 18.3 million hectares to 26.8 million hectares. Due to the accelerated land reclamation, irrigation and improvement of land area for agricultural production, the area of forests and aquaculture has increased (The Ministry ..., 2016). Land degradation in Vietnam has tended to increase due to the negative effects of climate change, erosion processes and socio-economic development.

It should also be noted that intensive rice cultivation, the basis of food and export crops, causes soil degradation, water pollution, loss of biodiversity and an increased greenhouse gas emissions (Agricultural ..., 2017). At the present time, in connection with the development of industrial zones and settlements, there is a tendency to reduce the area of agricultural and forestry land. Inefficient management of land and water resources at all levels and lack of good governance and the legal framework to address the problem of growing pressure on limited resources lead to an acceleration of land degradation that affect the rural communities and society as a whole.

To prevent negative processes in the use of land resources, to develop methods for the effective use of land in Vietnam, to make environmentally balanced decisions related to the implementation of actions on land, regular and constantly updated information on the state and trends of land resources is needed. The important socio-economic and ecological significance of lands brings to the fore the tasks of land management and the control of their condition. The monitoring of the state of the land used, in addition to its economic importance, also has a pronounced ecological orientation, ensuring, in particular, decision-making and carrying out activities that contribute to maintaining favorable living conditions of the population and the sustainable development of society.

One of the most effective and widely used in world practice methods of land management and control is the WOCAT system (World Overview of Conservation Approaches and Technologies), a global network for sustainable land management (SLM), which promotes the documentation, sharing and use of knowledge in support of adaptation, innovation and decision-making in the field of SLM (WOCAT …, 2016).

The purpose of this work is to analyze and evaluate the rational use of land in North Vietnam using the example of the Suoi Sap catchment area.

The following tasks were solved: to evaluate the existing economic use of the territory; forecast the development of erosion processes; proposals for the development and application of innovative technologies for the economic use of the territory.

Object and Research Methods

Son La province is located in North Vietnam. Its administrative center is the city of the same name. It includes 12 counties and 1 city of provincial subordination. The area of the province is 14210 km^2, according to this indicator, it is the third in Vietnam. The population is 1 million 10 thousand people. Son La is a predominantly mountainous province. There are many mountains and hills in it. Between them rivers and streams flow through the valleys. The climate is subtropical monsoon. The average annual temperature is 21°C, which is 3-4 degrees lower than in the neighboring provinces to the East. In the winter months, it can drop to 9°C, in May-September it can rise to 31°C. The average annual rainfall is about 1500 mm (Son La province, 2019). The rainiest months are June-August (250-310 mm per month).

The province has the largest river reservoir in Vietnam, which is formed by the “Son La” hydroelectric dam. This hydropower plant is the largest in South East Asia. The height of its dam is 138 meters. The catchment area was selected in the province. The catchment area is 26748.7 hectares (267.49 km^2), the perimeter is 77.6 km. The length of the river tributary is 161.7 kilometers. The compactness coefficient is $Kc=0.28\ P/A^{0.5}$, or the Gravelius’s index $K_G=1.33$ (Fig. 1).

The increasing pressure on natural resources leads to accelerated degradation of land and water resources, on which the well-being of rural communities and society as a whole depends. Land management, as a rule, is decided on a one-time basis, too often ignoring or only selectively applying useful knowledge and experience accumulated over many years in different regions (Huong, Kiseleva, 2018).

For predictive calculations of soil runoff values, the universal soil loss equation developed in the USA was used (Wischmeier, Smith, 1978):

$$Q=0.224\ R\ K\ LS\ C\ P, \qquad (1)$$

where Q is soil loss from erosion, kg/m^2 per year; R is the complex characteristic of the eroding ability of rain; K is a complex characteristic of soil properties that determine its erosion properties (water permeability and erosion resistance); LS is a complex characteristic of topographical factors; C is the complex characteristic of the influence of the farming system on soil washing; P is the complex characteristic of the effectiveness of various anti-erosion measures.

For the development of Sustainable Land Management (SLM) Technology in the catchment area, 5349 hectares were allocated for intensive agricultural use. The territory of the catchment basin is located in a mountainous area with the location of agricultural land on sloping lands. Analysis of the distribution of areas along the length and steepness of the slopes allowed to rank them as follows: 900 hectares with steepness up to 5 degrees; 1100 hectares were 5-10° and 3349 hectares were 10-20°.

Results

Analysis of the catchment area using the ArcView GIS program allowed us to rank its area according to the slope (table 1). Analysis showed the catchment area slopes predominate length of 500 to 2000 meters (87.7%), while slope steepness of these slopes varies from 10° to 40° (90.1%).

The soil cover of the catchment area is represented mainly by mountain lateritic soils. Information on the distribution by soil type is presented in table 2. Of the predominant soil types of the area should be noted Humic Acrisols/Humic Ferasols and Podzoluvisols/Dystric Podzoluvisols (Keys to Soil Taxonomy, 2010).

Cultivated land in the catchment area is estimated at 5349 hectares (53.5 km^2). The analysis shows that agricultural use of the land involved of slope steepness from 0° to 15-20° (table 1). The population living in the catchment area is approximately 19 thousand people and is mainly engaged in agricultural production. Peasant farms that produce products for self-sufficiency, cultivate plots with an average area not exceeding 1 hectare. Private farms differ from family peasant farms, using land plots of increased size due to the acquisition of rights to them from poor peasant farms on the basis of rent, the use of hired labor and the payment of additional tax.

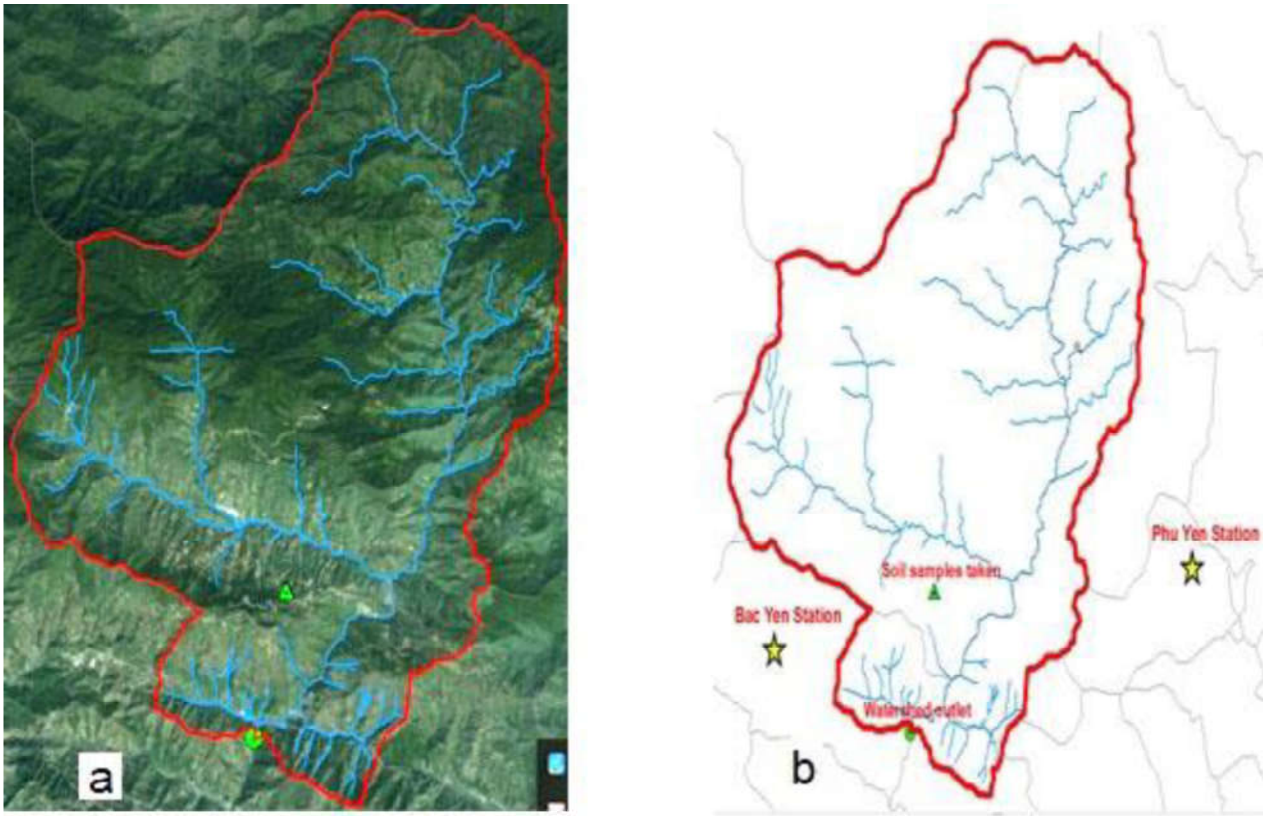

Fig. 1. Schematic maps of Suoi Sap catchment basin.

Agriculture of the province is diverse: meat and dairy farming (about 30 thousand heads for 2017), sericulture, cultivation of mulberry, coffee, tea, fruit trees (Agricultural ..., 2017; The Ministry ..., 2008).

Analysis of climate data shows that the greatest amount of precipitation falling in the form of rain falls in May-September (from 222 to 320 mm per month). During these months, the soil on the slopes of a sufficiently large steepness is exposed to heavy rainfall, leading to the formation of slope erosion.

According to research by Nguyen Van Duc (2013) humus as red-brown ferrallitic soils landscapes of Vietnam to a certain extent, reveals the functional relationship with the altitude above the sea level and the taxonomic (typical) characteristics of soils. The general geographical pattern is the high humus content, which quantitatively varies from 4.8 to 13.0%. The minimum humus content is characteristic of forest landscapes soils with relatively low topographic elevations (450-550 m). The humus content in the soils of landscapes located at an altitude of 700-800 m varies between 5.8-8.5%, reaching a maximum (12-13%) in the soils of landscapes located at altitudes of more than 1000 m above sea level (Nguyen Van Duc, 2013).

It should be noted that such a pattern can be traced for landscapes not subject to intensive economic use. The precipitation of a significant amount of rainfall, confined to the summer months, leads to the formation of surface water flow and soil washout. These processes lead to soil degradation. The effects of erosion degradation of soils and land cover degradation are diverse

(Le, 2015). The main indicators are the decrease in the power of the fertile layer of soils, the deterioration of their physical, chemical and biological properties, changes in granulometric and mineralogical composition, defragmentation of the soil cover. Evaluation of the results of erosion degradation is difficult and depends on an expert who determines the choice of several of its primary indicators. The power of the humus horizon is the main and easily determined parameter of erosion control in the field conditions. This parameter of the morphological structure of the profile, along with soil humus content, is used in many classifications of soil erosion and evaluation of the intensity of soil erosion losses.

Table 1. Distribution of catchment basin by altitude and slope degree.

DEM class	DEM* (m)	Area		Slope class	Steepness (degree)	Area	
		ha	%			ha	%
1	0-500	903.9	3.4	1	0-10	2007.5	7.5
2	500-1000	6665.2	24.9	2	10-20	8131.5	30.4
3	1000-1500	10013.9	37.4	3	20-30	11337.4	42.4
4	1500-2000	6780.8	25.4	4	30-40	4621.3	17.3
5	2000-2500	2250.7	8.4	5	>40	648.0	2.4
6	>2500	131.2	0.5	–	–	–	–
	Total:	26745.8	100.0		**Total:**	26745.8	100.0

Notes to table 1: *DEM – digital elevation model.

Analysis of samples (eroded and non-eroded) of soil selected by us in the catchment area showed that as a result of erosion processes there is a decrease in humus content from 5.4% to 3.5%. In washed soil there is an increase in the content of nitrate and ammonium nitrogen. The mobile P_2O_5 and K_2O practically do not change. pH_{H2O} and pH_{KCl} are 4.8-4.5 and 3.8-3.7, respectively.

Based on the available data, we carried out a preliminary calculation of a possible soil washout from slopes of 700 meters long and a steepness of 10-15°. Maize is cultivated on the field. The intensity of precipitation was 3.0-3.5 mm/h. Calculations have shown that under the given conditions for a one rain, the soil washout may be 2.0-2.5 kg/m^2 (20-25 t/ha).

Therefore, the organization of rational use and protection of land is one of the most important conditions for improving the economic performance of agricultural production. At the same time, land management plays an important role, which allows using the system of economic, technical, legal, environmental protection and other measures to organize the effective use of land, to ensure the rational organization of the agricultural territory.

The WOCAT (World Overview of Conservation Approaches and Technologies) international programme was used to develop rational and reasonable methods of economic use of the territory. On the basis of this system for the territory of agricultural lands with an area of 5349 hectares the Technology of LSM was developed: "Sustainable land use of the territory of the catchment area of Suoi Sap" (WOCAT …, 2016). The development of this Technology resulted in the following main provisions and recommendations.

1. In areas located in the lower parts of the slope lands (with a slope of up to 5 degrees) in order to prevent the development of water erosion, it is recommended to create ramparts-terraces with a wide base. The creation of such walls-terraces contributes to the retention of the surface flow of water and soil washout between the terrace spaces. The allowable distance (l) between the terraces is calculated by the formula: $l \leq h^2 r \sigma T / 2I$, where h is the working height of the wall, m; r is intensity of precipitation, m/s; σ is runoff coefficient; T is time of formation of surface runoff, s; I is

the tangent of the angle of the slope. The distance between the walls is calculated on the stock of 10% security. Walls-terraces are built on the horizons of the area. The height of the walls is 0.30-0.60 m, the base width is 8-12 times the height. The ends of the wall are wrapped up the slope at an angle of 120 degrees and gradually nullify. In areas of excessive moisture, it is advisable to lay a ditch along the excavation slope to remove excess water. Ditches are created with a small longitudinal slope (not more than 0.005) to dump excess water on the deserved watercourse. The area of land suitable for the creation of ramparts-terraces with a wide base according to our calculations is 900 hectares.

Table 2. Area and types of soils in the territory of Suoi Sap catchment basin.

FID*	Depth (cm)	Unit code	Area (ha)	Soil type groups
0	91	Ha	4504.1	Humic Acrisols/Humic Ferasols
1	93	A	1077.3	Podzoluvisols/Dystric Podzoluvisols
2	87	Hk	1460.3	Humic Acrisols/Humic Ferasols
3	93	A	546.4	Podzoluvisols/Dystric Podzoluvisols
4	0	River	15.2	River
5	93	A	3227.7	Podzoluvisols/Dystric Podzoluvisols
6	81	Fs	3942.8	Ferralsols/Ferralic Acrisols
7	90	Hs	1077.7	Humic Acrisols/Humic Ferasols
8	91	Ha	5348.7	Humic Acrisols/Humic Ferasols
9	90	Hs	1470.4	Humic Acrisols/Humic Ferasols
10	91	Ha	265.2	Humic Acrisols/Humic Ferasols
11	91	Ha	647.7	Humic Acrisols/Humic Ferasols
12	93	A	26.5	Podzoluvisols/Dystric Podzoluvisols
13	90	Hs	900.4	Humic Acrisols/Humic Ferasols
14	81	Fs	762.3	Ferralsols/Ferralic Acrisols
15	81	Fs	568.3	Ferralsols/Ferralic Acrisols
16	81	Fs	317.1	Ferralsols/Ferralic Acrisols
17	75	Fk	544.0	Ferralsols/Ferralic Acrisols
18	96	D	1.2	Dystric Gleysols
19	87	Hk	43.1	Humic Acrisols/Humic Ferasols
		Total:	26746.4	

Notes to table 2: *FID – digital elevation models.

2. On the steeper slopes (up to 10 degrees) in order to use them for growing valuable annual and perennial crops, it is recommended to create stepped terraces. When cultivating crops on these terraces, it is possible to use mechanized tillage and plant care. The terraces are elongated horizontally (a slight slope is allowed along the canvas) areas of various widths. The width of the canvas depends on the total slope steepness. The mechanism of anti-erosion action of terraces is to reduce the speed of water movement and increase its absorption into the soil. In areas with excessive moisture along the excavation slope they lay a ditch for drainage. At the same time a small longitudinal slope is attached to the canvas of the terrace. In the cross section of the canvas terrace may be horizontal, have a direct or reverse slope. The area for creating these hydraulic structures is 1100 ha.

Table 3. Average climatic indices in the territory of Suoi Sap catchment basin, according to the data of Bak Yen and Fu Yen meteorological stations.

Month	Temperature, °C	Rainfall, mm	Humidity, %	Evaporation, mm	Number of rainy days, n
1	15.5	39.4	81.2	68.0	4.9
2	17.6	28.9	79.9	76.1	4.5
3	20.4	54.5	80.0	92.4	7.0
4	24.0	129.9	79.1	103.8	11.7
5	26.1	231.7	78.3	113.4	15.7
6	27.2	248.5	80.1	102.2	15.6
7	26.8	320.9	82.9	85.3	19.5
8	26.3	307.6	84.6	67.8	19.1
9	25.2	222.3	83.6	69.4	13.4
10	23.3	113.0	81.6	76.7	9.2
11	20.1	27.9	79.3	81.4	5.5
12	16.5	27.1	79.1	75.4	4.3

3. The creation of terraces on the steeper slopes is aimed at the economic use of these lands. Given the fact that on these slopes it is difficult to use equipment to create terraces, it is necessary to provide manual labor. The mechanism of anti-erosion efficiency of these terraces is similar to the terraces described on the slopes of lower steepness (see previous version). These terraces also consist of the following elements: canvas (with a direct or reverse slope), excavation and bulk slopes. Terraces with a direct slope (4-6°) economically most profitable. In their construction requires a smaller amount of excavation. Terraces are elongated horizontally (allowed slope along the canvas no more than 0.003-0.005) platforms of different widths. With a slope of 8-10° width of terraces is usually 6-8 m at 10-15° is 4-6 m, with a slope of 15-20° is 3-4 m. Depending on the width of the canvas terrace it is used for growing citrus (tangerines, lemons, grapefruit, etc.) or for tea plantations. In areas where the humus horizon has a small capacity and is underlain by a rocky base, vertical slopes can be formed in the form of a rocky wall. This provides a large useful area of the terrace and reduces the risk of erosion. To fix the slopes of the terrace is recommended to sow with perennial grasses or berry bushes. The area of land with steep slopes of 10-20° is 3349 hectares.

Economic calculations show that the cost of launching the Technology is us 85.5 US$ per hectare, and the cost of maintaining it is us 0.79 US$ per hectare.

The analysis shows that one of the main factors influencing the implementation of activities for the project is the need to explain to land users the feasibility of more efficient use of agricultural areas, taking into account the preservation of their fertility and ecological status in the process of intensification of agricultural production. The interest of land users and members of rural communities depends largely on financial investments and payback periods. The share of financial investments of land users will depend on confidence in obtaining significant profits after the introduction of the Technology. At the same time, weak infrastructure, complicated rules for acquiring land for property, inadequate labor qualifications and administrative barriers complicate the work of local businesses. Nevertheless, the country is undergoing a process of accelerated industrialization, which will undoubtedly have an impact on the development of agricultural production.

Summary

On the basis of the performed researches it is possible to make the following conclusion.

Agricultural production of the Socialist Republic of Vietnam is one of the leading sectors of the economy, ensuring the food security of the country. This contributes to the favorable agro-geographical position of Vietnam, allowing farmers to collect several crops per year. At the same time, there is a tendency to increase the cultivated area. Statistics show that in Vietnam there are more than 13 million hectares of land located on the slopes and at the foot of the mountains, which are gradually introduced into economic circulation. In most cases, primitive tools are used in agriculture and only 10% of the land area is cultivated by machines.

The rainy season falls on the warm period from May to September. Heavy rainfall leads to soil erosion, which is the main cause of land degradation used in agricultural production. Erosion washout is subjected to the upper, most fertile layer of soil. In addition, part of the fertilizers used in agriculture is carried away with the washed soil. There is pollution of water bodies by products of erosion washout.

To assess the sustainable agricultural use of land, the Suoi Sap catchment area of Son La province was selected. The analysis showed that this area is dominated by slopes with a length of 500 to 2000 meters (87.7%), while their steepness varies from 10° to 20° (90.1%). The soil cover of the catchment area is represented mainly by mountain lateritic soils. Mainly dominated by Humic Acrisols/Humic Ferasols and Podzoluvisols/Dystric Podzoluvisols soil types. Considering that the humus content in the soils of landscapes located at an altitude of 700-800 meters varies within 5.8-8.5%, the erosion resistance of these soils should be high enough. Cultivated land in the catchment area account for approximate calculations, it is 5349 hectares (53.5 km^2). The analysis shows that slope lands with the steepness from 0° to 15-20° are involved in agricultural use. Large steepness and length of the slopes contributes to the formation of water flows with high values of erosion velocities. On the basis of our data a preliminary calculation of possible soil flushing was carried out from the slopes of 700 meters in length and steepness of 10-15°. Maize is cultivated on the field. Rainfall intensity was 3.0-3.5 mm/hour. Our calculations have shown that when rain falls with an intensity of 3.0-3.5 mm/hour from the field where maize is cultivated in one shower can be washed away 20-25 t/ha of soil.

On the basis of the WOCAT system for an agricultural land area of 5349 hectares, the SLM technology was developed, including the following main activities aimed at the efficient use of these lands. The Technology provides for the creation of hydraulic structures on the slopes of various steepness, aimed at partial retention of surface runoff and reduction of soil loss. On slopes with a steepness of up to 5 degrees (an area of 900 hectares), it is planned to create walls-terraces with a wide base. The creation of such walls-terraces contributes to the retention of the surface flow of water and soil washout between the terrace space. Equations are given for calculating the distance between the terraces, taking into account the surface runoff of 10% of coverage.

On steeper slopes (steepness 5-10 degrees) with the purpose of their use for growing valuable annual and perennial crops, the creation of stepped terraces is recommended. The mechanism of anti-erosion action of terraces is to reduce the speed of water movement and increase its absorption into the soil. In areas with excessive moisture along the excavation slope, a channel is laid to drain water. The area for the creation of these hydraulic structures is 1100 hectares.

The creation of terraces on steeper slopes (steepness 10-20 degrees) is also envisaged. The mechanism of anti-erosion efficiency of these terraces is similar to the terraces created on the slopes of lower steepness. Depending on the width of the canvas terrace it is used for growing citrus (tangerines, lemons, grapefruit, etc.) or for tea plantations. On land where the humus horizon has a small capacity and is underlain by a rocky base, vertical slopes are recommended to be formed in

the form of a rocky wall. This provides a large useful area of the terrace and reduces the risk of erosion. To fix the slopes of the terrace is recommended to sow with perennial grasses or berry bushes. The area of these lands is 3349 ha.

The calculations made for the start-up costs of the Technology are 85.5 US$ per hectare, and the maintenance costs are 0.79 US$ per hectare.

Thus, the WOCAT system can be used to develop rational and reasonable methods of economic use of the territory. This system is aimed at using global experience in sustainable land management (SLM). This experience can also be the basis for government decision making.

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