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Socio-territorial Diagnosis and Action Plan for Indigenous Community Management of the Talatac Basin

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Abstract

The people of Talatac face severe food insecurity and poverty, with 98% of the population living in unfavorable conditions. Their main economic activity is barley cultivation and sheep grazing. The most pressing problem is low agricultural productivity, accentuated by the lack of an adequate irrigation system, especially during the months of water scarcity. A preliminary study suggests the implementation of a sprinkler irrigation system that would improve agricultural production, in line with the Sustainable Development Goals (SDGs), such as Zero Hunger and Sustainable Production and Consumption. The study includes the biophysical and socioeconomic diagnosis of the Talatac watershed, which covers 946 ha, of which 17.84% is dedicated to short-cycle crops and 2.34% to pasture. The watershed has erosion, rapid runoff, and waste contamination problems. The lack of attention from the Municipality of Cotopaxi has led the community to request technical support from universities, obtaining an initial budget of $552,893.74 for irrigation infrastructure, an unattainable cost for the inhabitants without government subsidies or NGO support. The study also proposes a sustainable management plan for water resources and soil and moorland conservation. It also proposes strategies to involve external actors in the financing and execution of the project, as well as the installation of a meteorological station to monitor climatic conditions and improve water use planning. The conclusions highlight the urgent need for an irrigation system, accompanied by solutions to conserve soil and water, as well as sustainable economic development to combat poverty and improve the community's quality of life.

Keywords: *Food Sovereignty, Irrigation Systems, Water Scarcity, Soil Erosion, Water Management.*

Introduction

Recognizing the right of the Talatac people to feed themselves on a regular and permanent basis, optimizing agricultural resources is a priority(Requelme, 2020). Food security and sovereignty (LORSA., 2009) entitles them to optimize their resources, using an irrigation system that covers water shortages in the dry months, in accordance with the sustainable development goals SDG 2 on zero hunger, and SDG 12 on sustainable production and consumption (Cachipuendo et al., 2017; Fesbal, n.d.; Requelme, 2020). It is necessary to implement sprinkler irrigation systems that generate sustainable pasture production (Cachipuendo et al., 2017)

The struggle for irrigation water in Talatac has been unattended for several decades by the Municipality of Cotopaxi whose competence is to plan, build, operate and maintain irrigation systems (Art. 263) (Cachimuel & Cachipuendo, 2020b; CRE., 2021). The lack of attention has motivated the people of Talatac to seek technical assistance from universities to carry out preliminary and/or definitive studies (Cachimuel & Cachipuendo, 2020a).

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Poverty in Talatac is widespread among 98% of the population, and cultural identity has been lost due to migration. Productive activities are mainly barley cultivation and sheep grazing. The problem to be solved is low agricultural productivity. The objective of the project within the community management plan is: "Civil-hydraulic infrastructure designed and financed for irrigation water in Talatac".

The area of the basin is 953 ha. 145 ha are cultivation plots and the pipeline from the intake must run 6 km to the last plot. The first preliminary project was carried out by the Faculty of Engineering of PUCE (Murillo, 2020). The budget for the reservoir, conduction and distribution pipeline amounts to $552,893.74 (not including catchment). The cost of the work cannot be financed by the residents of Talatac; it needs to be subsidized by the State and/or NGOs. The beneficiaries are 224 inhabitants. Alternative, lower cost projects should be identified. The GAD Provincial de Cotopaxi and the Secretaría Nacional del Agua have not been directly involved in the project.

Materials and Methods

location

Figure 1 shows the location of the study area in Taltac – Zumbahua Parish – Pujilí Canton – Cotopaxi Province – Ecuador.

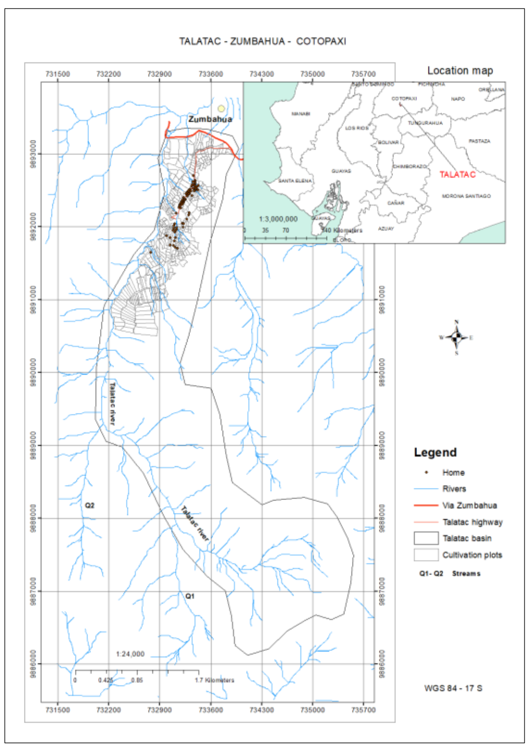


Figure 1. Talatac-Zumbahua Study Area (Coordinate system: Datum WGS 84 – Projection UTM Zone 17 S) (IGM., 2017).

Metodology

The research methodology for the water management project in the Talatac watershed is based on an integrated approach that includes the following key components:

Socio-territorial diagnosis.

a. Biophysical

The topography, soils and vegetation of the watershed are analyzed, highlighting steep slopes, soil type, and predominant vegetation.

b. Socioeconomic

The community of Talatac has a mostly indigenous and impoverished population, with low schooling and strong dependence on agriculture and grazing.

c. Environmental

There are problems of water scarcity and contamination due to degradation of the moorland by grazing and agrochemical use.

d. Actors

The participation of key stakeholders such as the Talatac Irrigation Board and PUCE is described, as well as the lack of consensus to advance in the financing and approval of the irrigation system.

Hydrological Monitoring and Data

Flow monitoring and the installation of a meteorological station are proposed to evaluate water use and the impacts of climate variability.

Soil Studies

The physical and chemical characteristics of the soils are analyzed, indicating erosion, nutrient content and the need for verification of cultivation areas.

Problem Analysis and Solutions

A problem analysis is performed with a “problem tree” highlighting the most critical problems. A “solution tree” is proposed with alternatives such as improving agricultural productivity and implementing an irrigation system.

Strategies and Community Management Plan

Strategies are established for the financial and technical management of the irrigation system, with community participation. Objectives are proposed such as improving education, increasing agricultural productivity, and creating agricultural savings and credit cooperative.

Implementation

A logical framework matrix is proposed for the design of water catchment, conduction and distribution works, with the participation of universities to reduce costs.

The methodology integrates technical analysis, stakeholder participation, socioeconomic and environmental diagnosis, and proposals for viable solutions with a focus on community participation

Results

Epistemic framework

The irrigation water management plan will be based on the Talatac River basin and will consider not only the technical aspects of water management, but also the environmental, economic, and social aspects of the basin.

Socio-territorial diagnosis of the watershed

Biophysics

The Talatac watershed covers 946 ha. The main river and its secondary streams total 20 km. The basin elevations range from 3560 to 4520 masl. Seventy-eight percent of the basin has slopes greater than 25% and 34% of the basin's territory has slopes greater than 40%. Soils up to 3 m deep are found on rock of the Pisayambo Formation. The soil is clay loam in 55%, sandy loam in 34% and loam in 11%. 16.35% of the Talatac basin is rocky outcrop. **Moorland** 54.21%. Wetland herbaceous vegetation 7.93%. Short-cycle crops are 17.84%. Cultivated pasture 2.34%. Population and roads 1.33%. There are environmental units. The 85.64% are cold peaks of the western mountain range of paleoglacial form. 14.36% are slopes and lower relief of the inter-Andean basin on andesite rock of the Pisayambo Formation.

Socioeconomic

Talatac is one of the 12 communities of the Zumbahua parish, with 224 inhabitants. Ninety-nine percent of the population is indigenous. Illiteracy is around 41%, with a maximum schooling of 6 years. There are two moderately equipped health centers about 5 km away. Poverty is widespread among 98% of the population and cultural identity has been lost through migration. Productive activities are mainly barley cultivation and sheep grazing (GAD Zumbahua, 2018).

Environmental

The population perceives that drinking water is scarce, especially during the summer, due to the degradation of the páramo (High plateau with very cold, dry climate and Andean grasslands). There is no infrastructure for long-term water reserves and river water is contaminated with garbage, mainly plastics. The wetlands and springs are also contaminated by grazing and crops that use agrochemicals to increase productivity (GAD Zumbahua, 2018).

Actors and organizational systems of the basin

Figure 1 shows the map of public, community and academic actors that should be involved in achieving an irrigation system for the Talatac watershed.

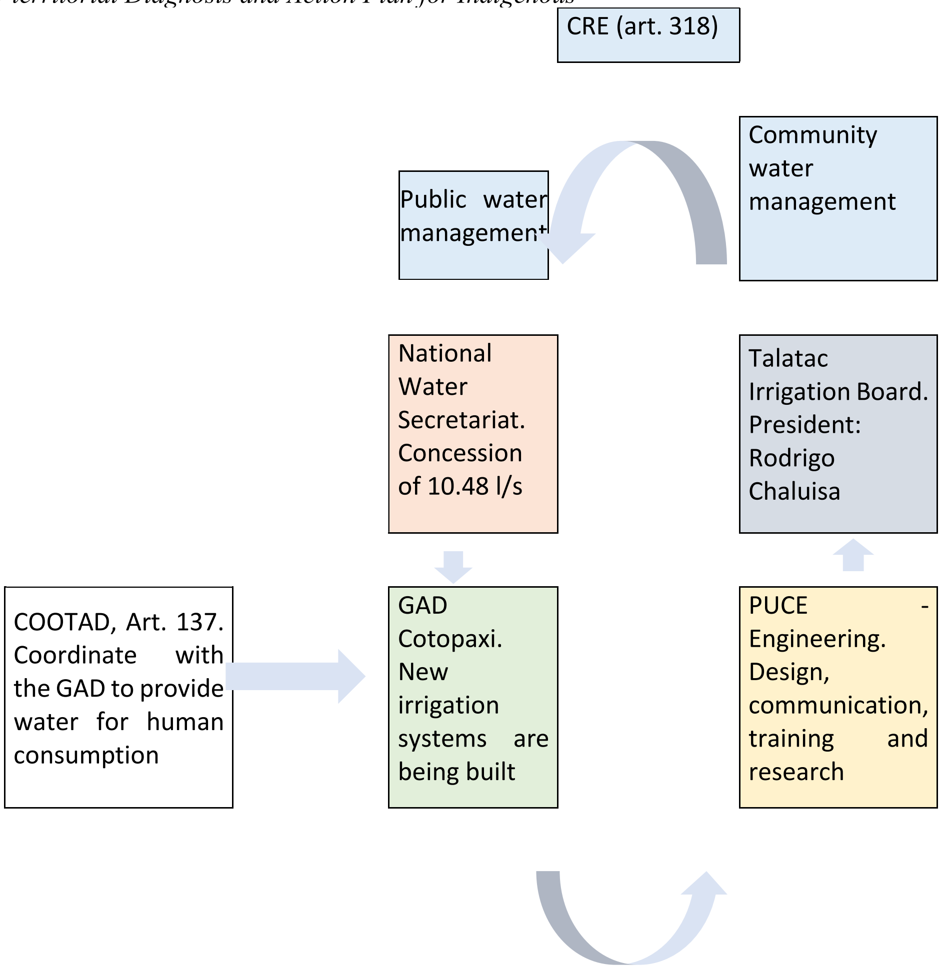


Figure 2.

Map of stakeholders for irrigation water management in Talatac (COOTAD., 2019; CRE., 2021; LORH., 2014)

The National Water Secretariat has concessioned 10.48 l/s of water for irrigation in Talatac. The Talatac Irrigation Board, represented by its president: Rodrigo Chaluisa has requested the hydraulic-structural design of an irrigation system for Talatac to the Civil Engineering career of PUCE. PUCE accepts the project involving soil laboratory, professors and students as Community Service and Thesis projects (Murillo, 2020) (Murillo, 2020).

To date, the actors with a common objective: “irrigation system for Talatac”, have been the Junta de Agua de Riego Talatac and the Faculty of Civil Engineering - PUCE. The Provincial Government of Cotopaxi and the National Water Secretariat have not participated directly in the project. The problem of lack of irrigation water for Talatac is clear, the solution (approval and financing) has not yet been found due to lack of consensus among all stakeholders. New actors such as NGO's should be considered to help manage the governance networks and get the signature, approval of hydraulic-structural plans and financing of the work (Morales & Cadena, 2021).

Hidrology

The main runoff is represented by the Talatac River and its contributing streams with a length of 20 km. Flows have yet to be measured at various points and in various areas. The Secretariat of Water has granted a right to use a flow of 10.48 l/s for irrigation water (Murillo, 2020). Figure 3 shows the low precipitation from June to November, with an annual monthly average of 100 mm.

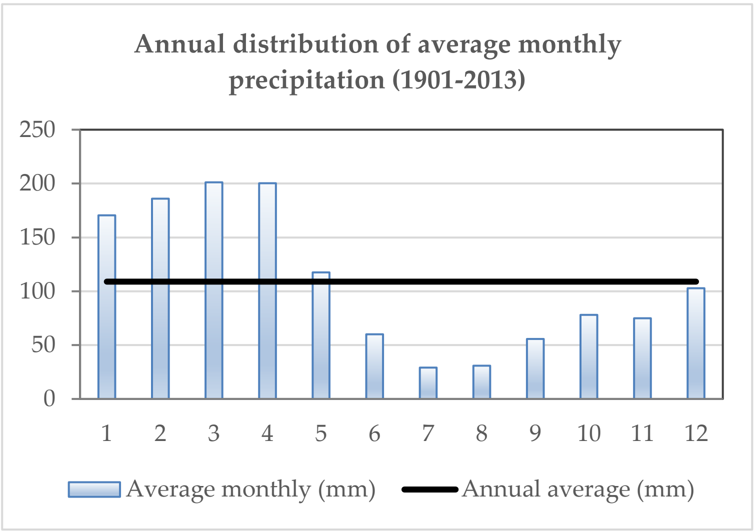


Figure 3. Historical Monthly Rainfall, Pilaló Years 1991-2015 (INAMHI, 2019; Sánchez, 2022)

Soils

In four pits in the Talatac cultivation area; the organic soils are 50 cm thick (moderately deep) and the inorganic soil is 0.8 to 1.7 m thick, giving a soil-on-rock thickness of 1.3 to 2.2 m. Organic soils are (OL-OH) and inorganic soils are (ML-SM). ML: inorganic silts of low compressibility; and SM: silty sands. The soils show moderate erosion and rapid runoff due to steep slopes. They have medium-high P and K, low to medium N. High Ca, Mg, Fe and Cu content. Medium Zn. The soil is slightly acid and not saline (Sánchez et al., 2019). Soil physicochemical data must be verified in areas close to the bedrock and in the initial area of the páramo where new cultivation plots are proposed by the population of Talatac.

Forests, Vegetation

There are no forests in Talatac. Páramo grasslands predominate in more than 50% of the Talatac watershed. There is less than 8% herbaceous wetland vegetation and 18% short-cycle crops (barley). The areas where native forests can be planted to conserve soil and water should be identified.

Base maps for irrigation and ecological management

Figure 4a, shows the topographic map with contour lines every 20 m. The elevation ranges from 3560 to 4520 meters above sea level, with a height difference of 960 meters.

Table 1 describes the slopes in percentage. Slopes greater than 12% up to 25% correspond to 22.16% of the territory. Slopes greater than 25% up to 40% account for 43.4% of the territory. Slopes greater than 40% to 70%, 27.39%. Slopes greater than 70% to 100% 7.05% (Figure 4b).

Pending	**Area**	**Territory**
%	**Ha**	**%**
> 12 - 25 %	209.64	22.16
> 25 - 40 %	410.58	43.40
> 40 - 70 %	259.07	27.39
> 70 - 100 %	66.65	7.05
		100.00

Table 1. Slopes And Their Corresponding Area in Talatac

Table 2 shows the soil texture (Figure 4c). Clay loam accounts for 45.44% of the area, sandy loam for 28.44%, and loam for 16.99%. 16.99% of the basin has a rocky outcrop without soil.

Texture	Area - Ha	%
Clay loam	429.81	45.44
Sandy loam	269.01	28.44
Loam	86.42	9.14
Not applicable	160.71	16.99
		100.00

Table 2. Talatac Soil Texture

In Table 3, we have the geology of the Talatac basin (Figure 4d), distinguishing the Pisayambo Formation with 74.68% of the territory. The rest are glacial, alluvial and colluvial deposits. The Yunguilla Formation appears with 0.57%. The Pisayambo Formation is dominated by pyroxenic andesites over pyroclasts, coarse breccias and agglomerates in the lower unit with ages of 5 to 6 Ma (Figure 4e) (Villares, 2010).

Geology	**Area - Ha**	**%**
Pisayambo formation	706.47	74.68
Fluvio-glacial deposits	80.44	8.50
Colluvio-alluvial deposits	80.05	8.46
Glacial deposits	50.99	5.39
Hillside deposits (colluvial)	22.59	2.39
Yunguilla formation	5.41	0.57
		100.00

Table 3. Geology of the Talatac Basin

Table 4 shows that 16.35% of the Talatac basin is rocky-rocky outcropping. Moorland 54.21%. Wetland herbaceous vegetation 7.93%. Short-cycle crops are 17.84%. Cultivated pasture 2.34%. Population and roads 1.33% (Figure 4f).

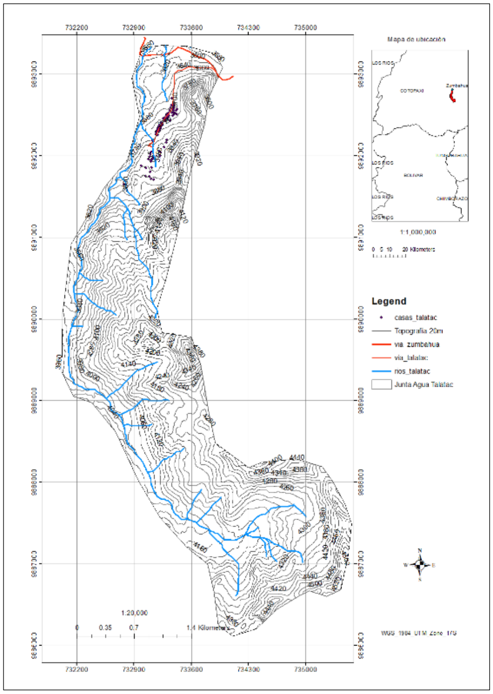
Soil cover	**Area - ha**	**%**
Highly altered herbaceous moorland	516.30	54.21
Short-cycle miscellaneous	166.24	17.45
Rocky outcrops	155.71	16.35
Modely altered wetland herbaceous vegetation	61.38	6.44
Cultivated grass	22.33	2.34
Highly altered humid herbaceous vegetation	14.23	1.49
Populated center	11.61	1.22
Cereals miscellaneous	3.74	0.39
Road network	0.95	0.10

Table 4. Classification Of Productive Systems and Vegetation Cover of Talatac

Table 5 shows the environmental units. 85.64% are cold peaks of the western mountain range, formed by paleoglacial formation. 14.36% are slopes and lower relief of the inter-Andean basin on andesite rock of the Pisayambo Formation.

Environmental unit	**Area - Ha**	**%**
Cold peaks of the range of paleoglacial inherited forms	810.15	85.64
Lower slopes and relief of the interandean basins on volcanism of the northern sierra	135.79	14.36
	945.94	100.00

Table 5. Environmental units of the Talatac basin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WGS 1984 UTM Zone 17S

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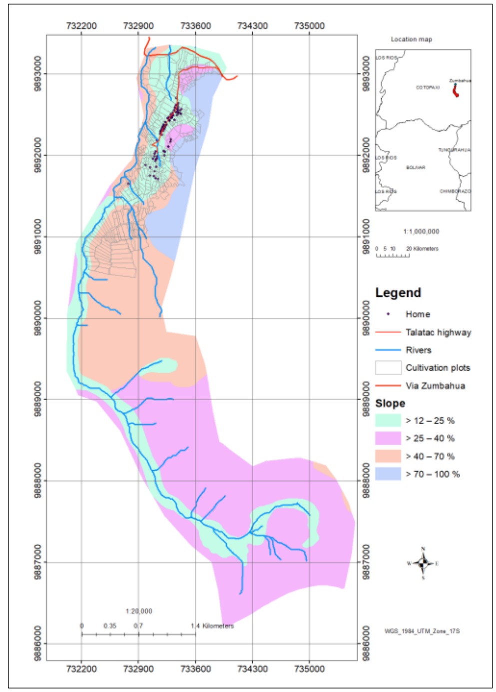
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Talatac highway
Rivers
Cultivation plots
Via Zumbahua
Slope
> 12 – 25 %
> 25 – 40 %
> 40 – 70 %
> 70 – 100 %
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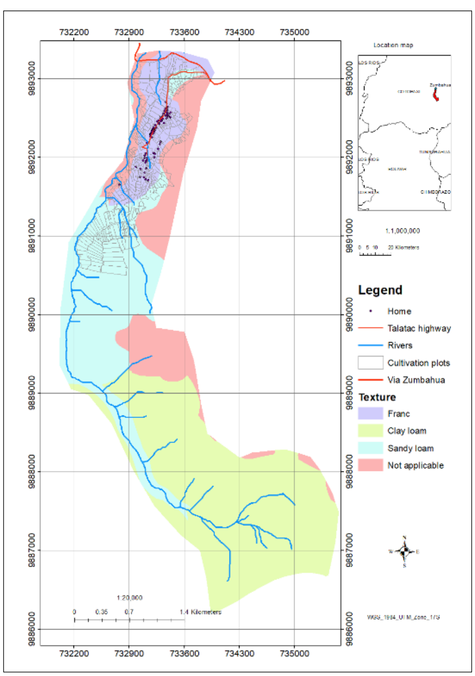
(b)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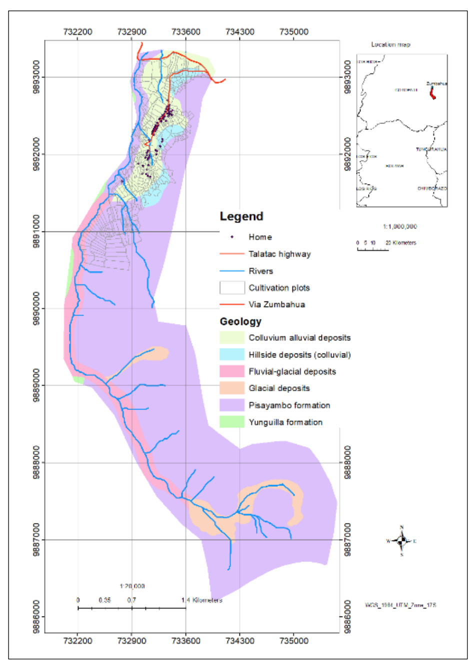
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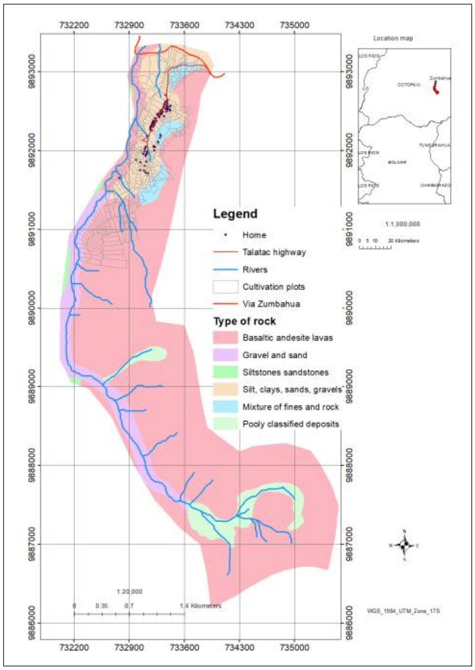
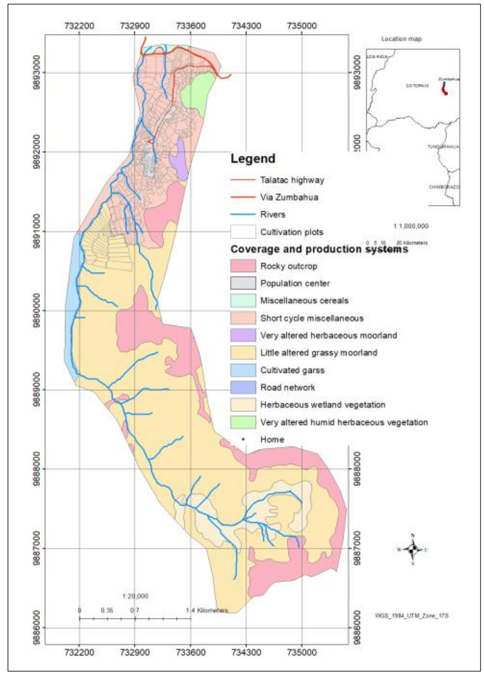
Home
Talatac highway
Rivers
Cultivation plots
Via Zumbahua
Geology
Colluvium alluvial deposits
Hillside deposits (colluvial)
Fluvial-glacial deposits
Glacial deposits
Pisayambo formation
Yunguilla formation
1:20,000
0 0.35 0.7 1.4 Kilometers

(c)



(d)



(e)

(f)

Figure 4.

This figure presents the following plans: (a) Topografico; (b) Pendientes; (c) Textura de suelo; (d) Geología; (e) Tipo de roca; (f) Coverage and production systems (SNI, n.d.).

Problems and Alternative Solutions

In Figure 5, the problem tree with its causes and effects can be seen.

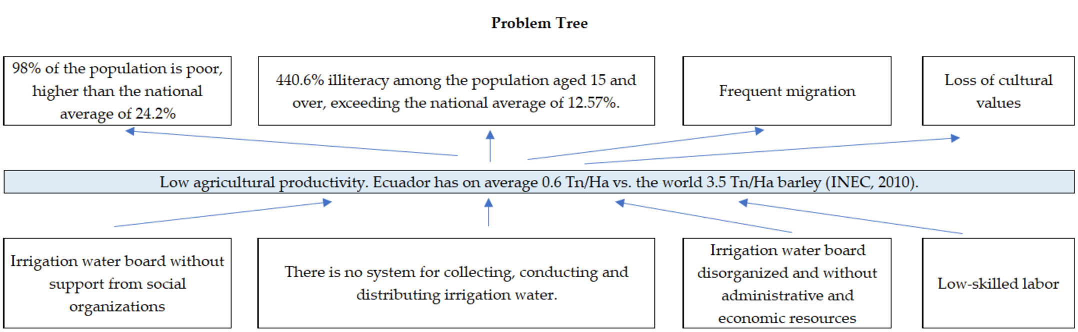


Figure 5. Talatac Problem Tree (Inec, 2010)

In Figure 6, the solution tree is shown, based on the problem tree.

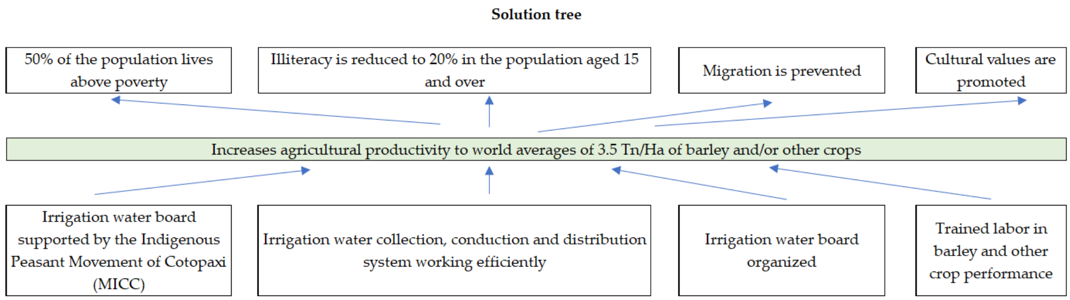


Figure 6. Talatac Solution Tree

In Table 6, we can see that the problems in order of priority are: poverty (25 points), low agricultural productivity (INEC, 2010) and lack of an irrigation system (21 points); illiteracy (18 points), migration (13 points) and environmental pollution (11 points).

Problem	**Who is affected?**	**How many affected**	**Since when**	**Frequency**	**Effect**	**Addition**
40.6% illiteracy among the population aged 15 and over, exceeding the national average of 12.57%	40% of the population	90 of 224	decades	40.6% of every 100 affected	Socio-economic backwardness	
assessment	5	2	4	2	5	**18**
98% of the population is poor, higher than the national average of 24.2%	The entire population	224	decades	100 out of 100 affected	Socio-economic backwardness	
assessment	5	5	5	5	5	**25**
Low agricultural productivity due to lack of irrigation. Ecuador has an average of 0.6 Tn/Ha vs. the world's 3.5 Tn/Ha of barley (INEC, 2010).	Population dedicated to agricultural activities and sheep herding.	157 of 224	decades	100 out of 100 affected	Socio-economic backwardness	
assessment	3	3	5	5	5	**21**

Frequent migration* of low-skilled labor (construction), causing**: family disintegration, violence, increase in vices and loss of cultural values	20% of the populatio n	45 of 224	decades	20 out of 100 affected	Loss of cultural values	
assessment	1	1	5	1	5	**13**
Wetlands and watersheds are polluted by grazing activities. There is no garbage collector; waste is dumped on land, in streams, ditches and canals; or it is burned, damaging the environment	20% de la población.	45 of 224	decades	20 out of 100 affected	Environment al impact	
assessment	1	1	5	1	3	**11**
*Causes of poverty and low agricultural productivity; **Causes of migration						

Table 6. Prioritizing the Problem in Talatac-Zumbahua

Community Management Plan

Vision: Sustainability of ecosystems, preserving the páramo in the medium term, oriented to food sovereignty.

Mission: Ensure irrigation service quality, quantity and coverage in all crop plots.

Principles: Equality in the distribution of irrigation water, mingas and benefits, participation of all irrigators in solving critical water conflicts in the assembly of the Tatatac irrigation water board, solidarity with irrigators who demonstrate reasons for non-payment or non-attendance at the minga, continuous auditing of accounting books and use of irrigation water only in the corresponding shift.

Strategies

Table 7 shows the strategies to be followed to achieve the objectives of the Talatac irrigation and productive improvement plan.

Scope	Strategies
Management	Form a financial management committee for the construction of the irrigation water system formed by the Talatac Irrigation Board, the Ministry of Water, the Ministry of Agronomy and Gad Cotopaxi.
Technical - environmental	Hydraulic and structural redesign of the irrigation system with costs less than $200.000 with support from the Ecuadorian university.
Economic	Continuous courses on barley production and specialized irrigation with support from the Ministry of Agriculture-Livestock and the Ministry of Water of Ecuador.
	Create a productive diversification program in Talatac with support from the Ecuadorian university.
Social	Agreement with the Ministry of Education for the education of older adults with support from the MICC

Table 7. Strategies of the Talatac Irrigation Plan

Proposed objectives, programs, and projects:

Table 9, 10 shows the objectives, programs and projects proposed in the community management plan.

Objetives		
Social dimension	O1	Encourage Talatac children to attend school every day
Technical environmental dimension	O2	Hydraulic, structural design and construction costs for the irrigation water system in Talatac.
Economic dimension	O3	Form a financial management committee to build the irrigation system.
	O4	Create an agricultural savings and credit cooperative.

Table 8. Talatac Objectives

Programs	
Achieving basic education for all.	P1
Improving agricultural productivity in Talatac.	P2
Diversifying productivity in Talatac	P3
Projects	
Encourage Talatac children to attend school every day.	P11
Form a management committee to finance and build the irrigation system.	P21
Design and finance civil-hydraulic infrastructure for irrigation water in Talatac.	P22
Create an agricultural savings and credit cooperative.	P31

Table 9. Talatac Programs and Projects

Execution

Developing project P22, we can see in Table 10, the logical framework matrix for the hydraulic and structural design of the intake, conduction, and distribution of irrigation water in Talatac. The universities can carry out the redesign of the project, which will reduce costs by more than 50%. For additional studies, the following will be used: soil laboratory, professors and students in the framework of University Social Responsibility projects and undergraduate dissertations.

LOGICAL FRAMEWORK MATRIX

	Narrative Summary	Meta: Base reference value	Meta: Value to be achieved	Activities	Objectively verifiable indicators	Means of Verification	Activity Manager
End	Support local sustainable development through the design of hydraulic infrastructure works for the Talatac Irrigation Water Board.						
Project	**Design and cost civil-hydraulic infrastructure for irrigation water in Talatac.**						
Result 1: diagnosis	Field visit carried out	80%	70%	Regional and in-situ evaluation of the project	Geographical position of the project	Location map	Civil Engineering-PUCE
Outcome 2: Planning and management	Base information obtained	100%	90%	2.1 Obtaining regional topography 2.2 Obtaining regional geology 2.3 Obtaining regional and historical climatology.	Contour lines lithology, structures… precipitation, temperature, insolation…	Topographic Plan Geological plan Isohyet plane	Civil Engineering-PUCE, Cotopaxi Provincial Government
Outcome 3: Implementation	In-situ field, laboratory and engineering studies carried out.	100%	55%	3.1 Catchment topography 3.2 Conduction topography 3.3 Climatology 3.4 Selection of supply sources 3.5 Hydrology 3.6 Geology 3.7 Geotechnics 3.8 Agrological 3.9 Survey of existing infrastructure 3.10 Hydraulic (catchment, conduction and 3.11 Structural (catchment, pressure relief tanks)	contour line contour line mm precipitation flow rates catchment rates lithology, structures… carrying capacity…. water demands by plot lengths, areas and elevations flow rates, energy dissipator, sand lengths, elevations, quantity of construction material	Topographic Plan Topographic Plan Georeferenced precipitation mm Georeferenced flow rates Hydrological plans Geological plan Laboratory report, geotechnical report Demand Existing infrastructure plans Hydraulic plan, technical report Structural plan, technical report	Civil Engineering-PUCE, Cotopaxi Provincial Government
Outcome 4: Project closure	Designed and costed civil-hydraulic infrastructure works.	100%	10%	4.1 Manuals and specifications 4.2 Unit price analysis 4.3 Technical-economic analysis	Hydrological, agronomic, hydraulic, unit costs, total costs Civil works indicators vs. construction costs	Technical specifications Construction cost report Conclusions, technical-economic recommendations of the project.	Civil Engineering-PUCE, Cotopaxi Provincial Government

Table 10. Logical Framework Matrix for Hydraulic Design of Irrigation Systems - Example

Discussion

Baseline Monitoring - Key Actions

Flow monitoring of the catchment area is proposed to be carried out by the president of the Junta de Riego on a quarterly basis. The flow will be measured by taking at least 5 measurements of water level, cross-sectional area and flow velocity. In addition, it is proposed to install a weather station in the catchment area of the Talatac watershed.

The percentage of soil dedicated to short-cycle crops and pasture should be verified. Define the geographic points of contamination or burning of garbage and grassland,

identifying those responsible. Propose training and awareness-raising for the Talatac population.

Project Costs

In Table 11, we can see the budget for: reservoir, pipeline and distribution, which amounts to $552,893.74. The cost of the collection is not considered.

Reference budget, May 2020	
Description	**US $**
Main pipeline	118189.04
Reservoir	49880.39
Distribution network	345013.67
Valve box	17915.44
Pressure-breaking tank	21895.2
Total	552893.74

Table 11. Reference Budget For Reservoir, Irrigation Water Conduction And Distribution for Talatac (Murillo, 2020).

In Table 12, the alternatives to solve the problems of Talatac can be observed, highlighting the design and construction of a system for the collection, conduction and distribution of irrigation water.

	Alternatives		
Issues	**1**	**2**	**3**
Reduce illiteracy	Formal education program for children	Education program for people over 18 years of age	
Reduce poverty	Increasing agricultural production with training in barley production and specialized irrigation	Create a savings and loan cooperative for agricultural production	
Design and construction of a system for collecting, conducting and distributing irrigation water	Financing of the irrigation system with a total cost of $500,000 (Murillo, 2020) by NGO´s and GAD Cotopaxi	Hydraulic-structural redesign of the irrigation system, seeking maximum costs of $250,000 and 100% financing by NGO´s and GAD Cotopaxi	Hydraulic-structural redesign of the irrigation system, seeking maximum costs of $200,000 and 50% financing by NGO´s and GAD Cotopaxi plus labor with community mingas (50%)
Reduce migration and loss of cultural values	Increase in agricultural employment	Productive diversification program	

Table 12. Alternatives to Problems

Table 13 rates the financing alternative for the Talatac irrigation system and shows that the redesign of the system should cost less than $200,000.

No.	**Alternative**	**Particip a-tion of priority groups**	**Possibility of achie-ving the objectives**	**Available resources and alliances**	**Social and environmental risks**	**Gender**	**Sustain-ability**	**Total**
1	Financing of the irrigation system with a total cost of $500,000 by NGOs and GAD Cotopaxi.	1	1	1	1	2	3	**9**
2	Hydraulic-structural rede-sign of the irrigation system, seeking maximum costs of $250,000 and 100% financing by NGO´s and GAD Cotopaxi.	2	2	1	1	2	2	**10**
3	Hydraulic-structural redesign of the irrigation system, seeking maximum costs of	3	3	1	1	2	2	**12**

	$100,000 and 50% financing by NGO´s and GAD Cotopaxi plus labor with community mingas (50%).							

Table 13.

Evaluation of alternatives to the construction costs of the Talatac irrigation system(DSC, 2013)

Scale: 3 = high; 2 = medium; 1 = low

Sources of financing and origin of funds

With an initial investment of approximately $560,000, considering 50 irrigation water users with 2-hectare plots, paying $105/user/month at a 10% interest rate over 20 years, the net present value (NPV) would be positive of $4,276.9. Income from barley sales does not cover the direct financing of the irrigation system for 20 years. With 100 hectares of barley planted, the income per user would be $1,120/ha/harvest (yield: 4.1 tons/ha, $0.5/kg, 1 harvest/year (Gómez et al., 2009; MAGAP., n.d.)), lower than the $1,260/year paid by the irrigation system. The irrigation system in Talatac must be subsidized by the state and/or NGOs. Alternative, lower-cost projects to the undergraduate study proposed by Murillo should be identified (Murillo, 2020)

Monitoring and Evaluation

a. Technology transfer for climate monitoring

A meteorological station should be placed in the Talatac water catchment area to periodically indicate the climatic parameters of the area. The data management of the station should be supported by an educational institution within the framework of "University Social Responsibility" projects. The data should be processed together with the flow rates measured in the catchment area to directly obtain the runoff and infiltration coefficient. In addition, the community members should be trained in the collection of flow rates and climatic data from the weather station.

b. Forest management and reforestation

Sustainable planning and management of water resources allows to meet the current and future needs of the population. For the protection of water sources (páramos) you need the collaboration of several actors: universities, NGOs, the State and the Talatac community.

c. Local economic development

In Talatac, agricultural production, local employment, food stability and security, and the opening of new markets should be promoted by identifying the strengths and opportunities of Zumbahua (head of the parish).

d. Soil and water management and conservation

Soil and water management and conservation are essential for ecosystem sustainability and food security. Soil degradation and water pollution are problems that promote erosion, desertification, and low agricultural productivity. Protecting water and soil improves agricultural productivity, ecosystem health, and people's quality of life.

Conclusions and Recommendations

A meteorological station should be placed in the Talatac water catchment to indicate the climatic parameters of the area on a regular basis. The station's data management should be supported by an educational institution within the framework of linkage and/or research projects (LOES, 2018). The data must be processed together with the flow rates measured in the catchment area to directly obtain the runoff and infiltration coefficient.

Of the 946 ha of Talatac, 16.35% is rocky outcrop, 54.21% moorland, 7.93% wetland herbaceous vegetation, 17.84% short-cycle crops, 2.34% cultivated pasture, 1.33% population and roads. The cultivated plots are 145 ha of which 48.44 ha are moorland. It is not recommended to cultivate the soil in areas close to the bedrock and in moorland areas.

The problems in order of priority in Talatac are poverty; low agricultural productivity and lack of an irrigation system; illiteracy; migration; and environmental pollution. The most relevant strategic objective is O2: “To increase agricultural productivity through a system of water collection, conduction and distribution of irrigation water in Talatac”.

The irrigation system in Talatac must be subsidized by the State and/or NGOs. Alternative projects of lower cost to the degree study proposed by Murillo [8] should be identified. The Ecuadorian university can carry out the corresponding additional studies, using soil laboratory, professors, and students in projects of linkage and research (LOES, 2018). To date, the actors with a common objective: “irrigation system for Talatac”, have been the Junta de Agua de Riego Talatac and the Faculty of Civil Engineering - PUCE. The Provincial Government of Cotopaxi and the National Water Secretariat have not participated directly in the project.

Research related to the Talatac watershed is recommended, such as: prioritizing areas for hydrological restoration using morphometric analysis, precipitation and NDVI (Sánchez, 2022) In addition, hydrological modeling for the Talatac River basin can be performed with software such as Swat.

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