PRACTICAL ADAPTATIONS OF ANCESTRAL KNOWLEDGE FOR GROUNDWATER ARTIFICIAL RECHARGE MANAGEMENT OF MANGLARALTO COASTAL AQUIFER, ECUADOR

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ABSTRACT

UNESCO Universal Declaration about Cultural Diversity of 2001 establishes that traditional and ancestral knowledge are heritage whose value goes beyond the originating communities. In fact, they are a source of creativity and innovation. Also, their recognition promotes social inclusion and participation. In rural areas such as Manglaralto, which is part of the coastal zone of Ecuador, its residents face the challenge of managing water. Community participation and ancestral practices have been relevant mechanisms to handle water problems. Both elements have allowed the inhabitants to develop and adapt techniques to recharge aquifers, which are a natural underground storage. The aim of this research is to analyze the practical adaptation for improving the application of artificial recharge through ancestral knowledge in a community research project with the support of ESPOL Polytechnic University for the management of coastal aquifer Manglaralto. Therefore, the methodological process includes: i) the Participatory-Action-Research (PAR) cycle through observation-reflection with the concurrence of the Manglaralto community through the Regional Board of Water in Manglaralto; ii) the sequential registers of community practices that respond to the growing demand for water in the river-aquifer context; and iii) an analysis of the practical adaptations for artificial aquifer recharge. The research study includes the implementation of dykes, "*tapes*" (historical term in Spanish for "dykes"), as part of ancestral knowledge. The dykes were made by the community with the technical support of the university and the interactive participation of the population. Hence, the *tapes* have been developed and improved through the trial and error method under the PAR framework. Currently, the dyke has evolved, as it has had several modifications from its first artisanal design to its technical construction within a pragmatic, economic and functional scheme. Consequently, the community shows how ancestral knowledge provides solutions for handling complex issues such as the artificial recharge of the aquifer.

Keywords: ancestral knowledge, aquifer, artificial recharge, PAR methodology.

1 INTRODUCTION

Water is a necessary and indispensable resource for human activities. From household use to use in all productive sectors of a country, this natural resource is considered an engine of economic and social development. In the world, the distribution of water is not equitable, so it is vital to carry out responsible and sustainable water management in the long term. Currently, water shortage comprises one of the major global environmental concerns [1], [2]. Gleick [3] Identified that 3% of the planet's water is fresh. From this percentage, 68.7% are frozen in the polar ice caps, while 30.1% comprise groundwater and only 1.2% is found in lakes, rivers, swamps and in the atmosphere [4]. Therefore, due to groundwater scarcity in percentage with respect to the total fresh water on the planet, it is one of the most important water reserves for humanity.

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The availability of freshwater resources is a challenge for many communities since it is a scarce resource that limits social and economic development [5], [6]. Concentrated in coastal regions, aquifers require appropriate management because more than half of the population lives there and covers 10% of the earth's surface [7].

Manglaralto rural parish is supplied with water from the Manglaralto coastal aquifer. However, as the time goes by, the population of the parish grows. This situation in to the lack of rain puts the aquifer in danger of depletion. This causes a drop in the water table of the wells [8].

In arid areas, such as the Santa Elena Peninsula (PSE, acronym in Spanish), our ancestors worked hard to recharge groundwater because they knew it was vital to subsist. In Ecuador, the inhabitants of the PSE have been developing ancestral techniques for the care and preservation of water, especially in rural areas. In locations where it is very difficult for the inhabitants to have potable water, they should seek for other measures to obtain this important resource [9].

In Manglaralto, this type of recharge occurs thanks to the implementation of the *tapes* (artisanal dikes) in order to increase the availability of water. This type of work comes from traditional knowledge and ancestral practices, which according to [10]; result from practical experiments of thousands of years of our ancestors. Yapa [10] ensures that our ancestors did not need money, machinery or university degrees. Moreover, their techniques are easy to understand because they are based on meticulous observations of the nature. Hence, these techniques are easy to implement because they use materials from the environment. Also, they are easy to modify and adapt to other sites because the assessment of the results is part of the experiential process. Therefore, in the project that CIPAT (Center for Research and Projects Applied to Earth Sciences) of ESPOL is carrying out in the area to recharge the aquifers, we have to raise awareness on the appropriate use and care of water.

The aim of this research is to analyses the practical adaptation for improving the application of artificial recharge through ancestral knowledge in a community research project with the support of ESPOL Polytechnic University for the management of coastal aquifer Manglaralto.

2 STUDY AREA

The area of interest includes the Manglaralto parish, PSE in Ecuador (Fig. 1). A coastal parish of 147 years old, where inhabitants obtain water from a single underground source. The coastal aquifer, managed by the Community Company called Regional Administrative Board of Drinking Water of Manglaralto (JAAPMAN, Spanish acronym), supplies water to 30,000 inhabitants [11]. Fig. 1 describes the location of Manglaralto parish in PSE.

3 METHODOLOGY

The Participatory Action Research (PAR) methodology is a process that harmonizes the activities of reality awareness through mechanisms of the community participation. Moreover, it involves the democracy in the planning and execution of development programs and projects for the improvement of the population living conditions [12].

Stage I – Water issue: includes collecting basic information from sources or references such as articles, theses, and project field reports of the study sector. In the Manglaralto parish of PSE, the most critical issue is the availability of water for human consumption, attention to tourists, and tourism derived businesses. Therefore, the sector's development is closely linked to the groundwater issue.

Stage II – River-aquifer system: lies in the specific characterization of the watershed data and the type of the aquifer system. In the Manglaralto parish, the community and social

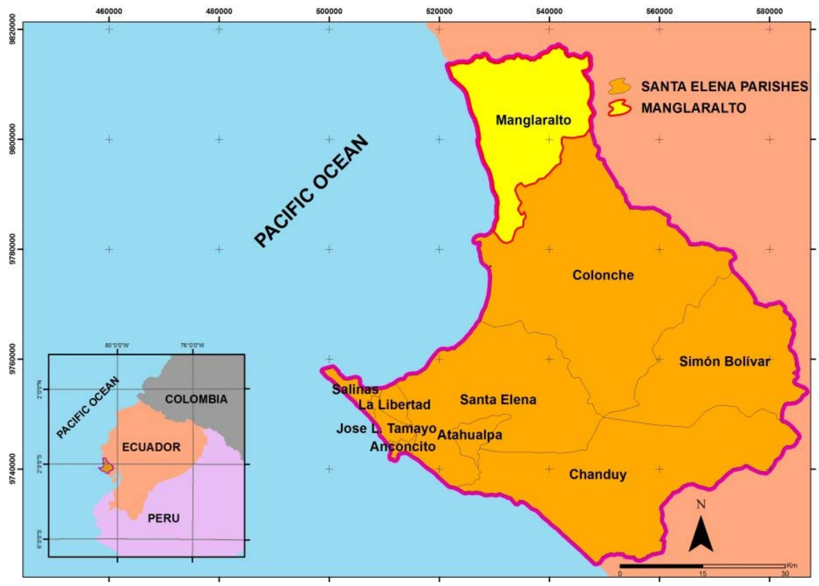


Figure 1: Location map of the Manglaralto Parish.

organization that deals with the water issue is the Regional Administrative Board of Drinking Water of Manglaralto (JAAPMAN). The board is a communal, social and political organization in charge of the administration of the existing water in the Manglaralto river basin. In academic works, research and projects linked with the society, the Center for Research and Projects Applied to Earth Sciences (CIPAT-ESPOL) works with the community through participatory models to respond to the growing demand for water in Manglaralto. Thus, CIPAT propitiate the conditions of current developments. The Participatory Action Research (PAR) method takes place through permanent interaction with the community to solve the water supply problems.

Stage III – Practical adaptations of ancestral knowledge: given the growing demand for water by the population and tourism businesses, in the PAR process, the community led by the JAAPMAN promoted a backward glance to the ancestral techniques and knowledge of water management and a review of its applicability in the XXI century. Hence, practical adaptations made since 2013 have addressed the issue and become a crucial factor in groundwater management. The adaptations occur in the field and constantly improve the recharge of the coastal aquifer. There are several models developed through the trial and error method and performed in community work by the JAAPMAN of Manglaralto.

4 DEVELOPMENT AND RESULTS

4.1 Stage I: Water issue

In PSE, the public company AGUAPEN E.P. in the three municipalities of the province manages the water supply. However, AGUAPEN E.P. service does not cover the Manglaralto parish. Thus, the Regional Administrative Board of Drinking Water of Manglaralto, (JAAPMAN), manages 12 drilled wells that only supplies water by pipeline to 42% of the population of the parish. The rest of the population obtains water from clandestine wells, delivery cars, canals and *albarradas* among other sources. Hence, the population assumes the consequences on health that this type of operation entails. One of the problems of water deficit in the parish of Manglaralto is the low flow due to the historical shortage of rainfall in the area. In addition, the level of fresh water wells drops gradually. This increases the danger of salinization of water due to its proximity to seawater [13].

All these circumstances and the fact that the Manglaralto aquifer is the only source of fresh water for the inhabitants of the area have cause a considerable reduction from 12 l/s in 2013 at 5 l/s in 2015 of the well exploitation flows [14]. In addition, water consumption of the population, has quintupled in 7 years, from 143,951 m^3 of water in 2008 to 593,177 m^3 in 2015. Fig. 2 illustrates the water consumption trend and the approximate volume of Manglaralto aquifer, which, due to growing demand of inhabitants has been facing changes in its content; this has been calculated and documented by [13].

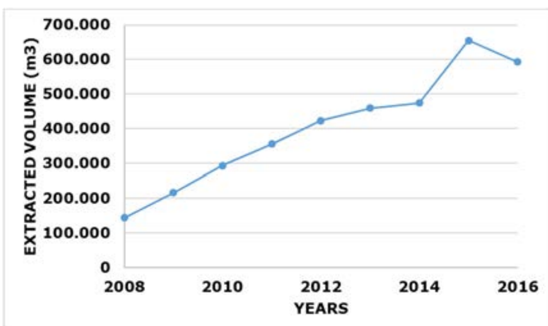
4.2 Stage II: River-aquifer system

4.2.1 Geology

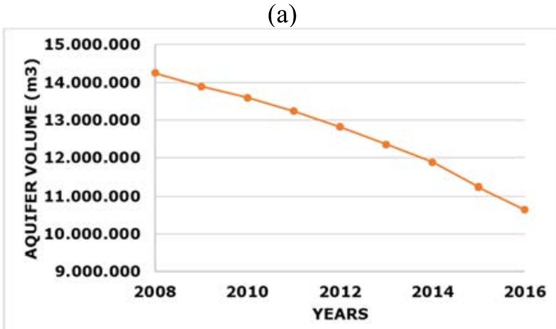
The geological formations found within the Manglaralto basin vary in ages from Upper Cretaceous to recent. It forms a thick series of sedimentary and volcano sedimentary rocks as shown in Fig. 3.

4.2.2 Geomorphology

Fig. 3 shows the shape of the relief, characterized by high hills located east of the sub-basin Manglaralto River derived from the Chongon-Colonche mountain range. To the west of the



(a)



(b)

Figure 2: (a) Water consumption 2008–2016, based on data from JAAPMAN; (b) Aquifer volume from 2008–2016. *(Source: Modified from [13].)*

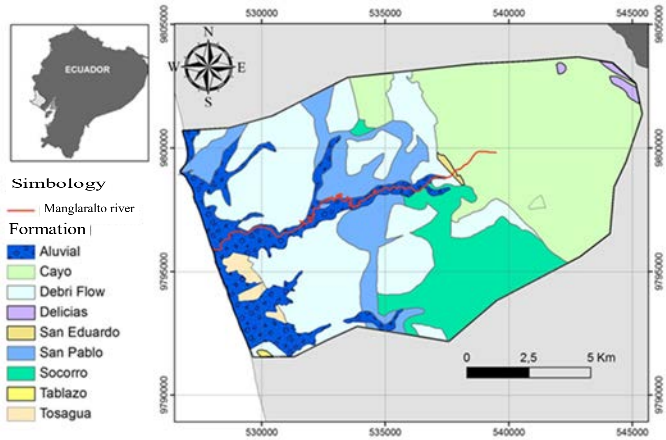


Figure 3: Relationship between the geomorphology of the sub-basin and its geology. *(Source: Modified from [15].)*

sub-basin, it also integrates wide valleys with a progressive decrease in altitude in its hills and areas of large alluvial terraces, coluvial terraces because of debris falls from the highest part of the slopes. Fig. 3 describes the relationship of the geomorphology and geology of the sub-basin.

Therefore, the alluvial material deposited along the Manglaralto River would increase its thickness as we move towards the lower part of the sub-basin. In the upper and middle part of the sub-basin, due to the formation's low porosity and permeability, they are not suitable to retain enough water to be considered as aquifers. These lithologies correspond to the impermeable layers that overlie the alluvial material of the aquifer in the Manglaralto River.

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4.2.3 Hydrology e hydrogeology

The hydrographic system of the north of PSE is formed by the rivers originating from the Chongon-Colonche mountain range and flow towards the west and southwest of the peninsula. In the Manglaralto basin there are also 3 main hydrographic basins: Manglaralto, Cadeate and Simon Bolívar rivers and some smaller mangrove drainages such as the Chico River and the Montañita or Chicharron river.

The Santa Elena peninsula presents a tropical mega-thermal climate from arid to semiarid. Annual precipitation cycle in the Manglaralto watershed varies between 200 and 700 mm/year during rainy season, January to April. In the other season (May to December), the average monthly precipitation values are very close to zero, as shown in Fig. 4.

In addition, the basin is divided into three parts: the upper-middle basin that reaches a height of 180 m.a.s.l. and provides the greatest amount of water to the river system, and the lower basin which is at the sea level. Here, the alluvial deposits are mainly composed of gravel, sand and silt. According to the model of the Manglaralto basin elaborated by [14] in

Fig. 5, the basement of this basin contains the clayey strata of the Fm. Zapotal and the Fm. Socorro.

A general characteristics summary of the river-aquifer system is presented in Table 1.

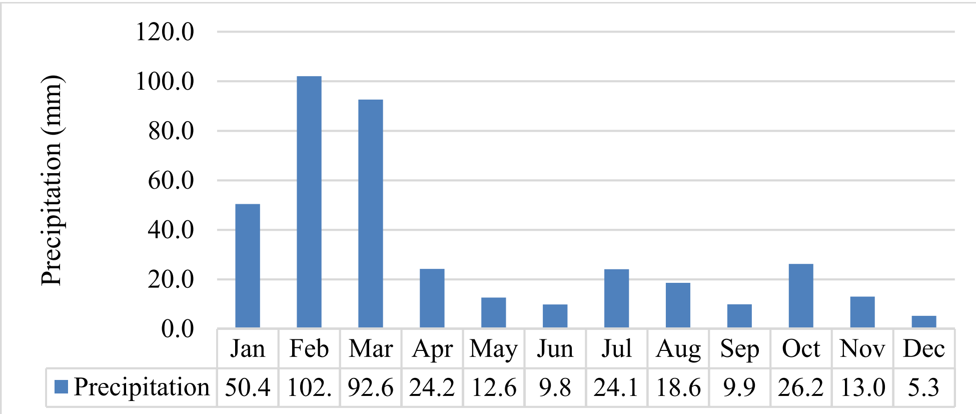

Figure 4: Average monthly precipitation – period 2000–2015. *(Source: Modified from [13].)*

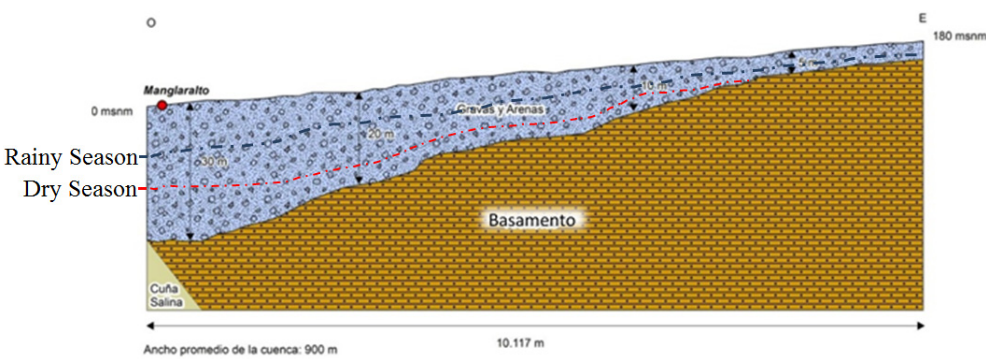

Figure 5: Profile of the Manglaralto river basin. *(Source: Modified from* [14]*).*

Table 1: Relevant data of Manglaralto river-aquifer system.

<table>
<tr><th rowspan="3">Manglaralto River</th><th>Precipitation (mm/year)</th><th>$Q_{average}$ (m^3/s)</th><th colspan="2">Season</th></tr>
<tr><td rowspan="2">200–700</td><td rowspan="2">0.01–0.02</td><td>Rainy</td><td>Dry</td></tr>
<tr><td rowspan="2">Jan–Apr</td><td rowspan="2">May–Dec</td></tr>
<tr><th rowspan="3">Manglaralto Aquifer</th><th>Infiltration (%-mm)</th><th>$V_{average}$ (m^3)</th></tr>
<tr><td>13%–21%</td><td rowspan="2">10.641.395</td><th colspan="2">Well extraction flow</th></tr>
<tr><td>(26–91) mm–(42–147) mm</td><td>12 L/s</td><td>5 L/s</td></tr>
</table>

4.3 Stage III: Practical adaptations of ancestral knowledge

Facing the shortage of rain problem and the imminent fact that the underground resource is running out due to the exploitation of water without an adequate recharge of the aquifer, dykes, called in ancestral knowledge as *tapes* (handcrafted), appear as a temporary solution. Concurrently, dams are economically viable tools for channeling water in the rainy season to meet the needs of the population during the scarcity time. *Tapes* or artisanal dykes is a denomination that the community members gave to the accumulation of rocks and sediments in certain parts of the river channel either to dam the water or allow to accumulate it.

Since 2013, the JAAPMAN has built *tapes* or artisanal dykes for water treatment along the Manglaralto River to favor a better aquifer recharge. The structures have evolved with the trial and error method (Fig. 6). Due to weaknesses in the design, some *tapes* failed during the rainy season (Fig. 7).

4.3.1 Current technical adaptation

Currently, the JAAPMAN has built a dike (technical tape) in the Manglaralto River. For this purpose, the JAAPMAN considered previous geological studies that involve an integral design of the dike and the rescue of ancestral knowledge. The structure of the dike will serve for the surface channeling of water, a better use of the underground recharge and the sustainability of the Manglaralto coastal aquifer.

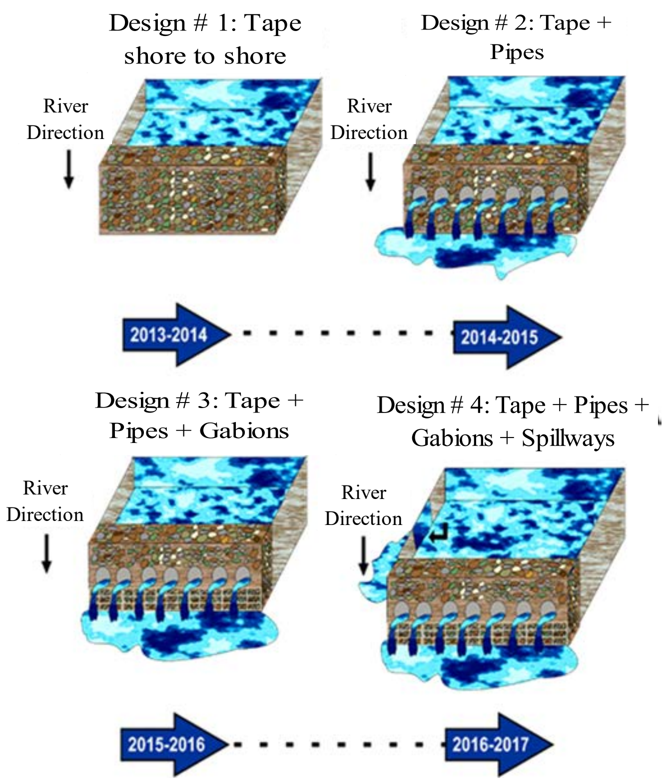

Figure 6: Block diagrams of different designs of *tapes* made by the JAAPMAN of Manglaralto. *(Source: [16].)*

Figure 7: Tape failure during the rainy season. *(Source: [15].)*

At present, the dike's construction is in the final phase, it is technical-craft. Thanks to the active participation of Manglaralto parish inhabitants, with some modifications and practical adaptations to the design because of the participatory working method. The technical part has been adapted to the technical-craft dyke, which can be observed its stages in Fig. 8.

4.3.2 Evolution by trial–error method.

The implementation of *tapes*, carried out by the JAAPMAN in Manglaralto, has been developed and perfected for the recharging of the coastal aquifer by means of the trial and error method. In this way, the "tape" has undergone several modifications since its first design, as detailed in Table 2, always in interaction with community under PAR process.

Figure 8: Construction stages of technical-craft dyke.

Table 2: Evolution by trial–error method made by the community of Manglaralto.

	Design 1 (2013–2014)	Design 2 (2014–2015)	Design 3 (2015–2016)	Design 4 (2016–2018)	Current (2018–2019)
Description	It involves collecting and stacking rocks and sediments, to prevent the passage of water.	It consists of placing 10 pipes along the dike (tape), which allows the passage of water.	It was implemented with gabions (metal mesh with stones), distributed along the axis of the tape.	This design had the characteristics of the other designs, with the implementation of spillways.	It consists of a concrete design with spillways and pipes along the axis of the dyke.
Problems	The erosion caused by the water ended up taking it away	Erosion continued to act more slowly, but its effects were accelerated by raising the water level due to rain.	The rocks did not provide the expected support; due to interconnected spaces allowed erosion.	Erosion effects were accelerated by raising the water level due to rain.	The construction has had some modifications respect to the original technical design.
Improvement	We attempted to minimize erosion with the implementation and laying pipes, which relieve pressure.	It was thought about implementing gabions, for better support.	The implementation of spillways was idealized.	For subsequent designs the use of concrete is projected.	For subsequent designs the use of floodgates in the spillways is projected for rainy seasons.

5 ANALYSIS OF RESULTS

The changes in the level of the aquifer are cyclical, and they correspond to periods of high rainfall, rainy seasons (January–April). Thus, they correspond to periods of natural recharge of the aquifer due to infiltration, and times of high water demand due to the tourist activity.

In Fig. 9, it is noticeable that in 2016, there was a decrease in the level. Later, we observe a leap in the values of the piezometric level which shows that there has been an accelerated recharge in the aquifer. This fact occurred because the JAAPMAN followed the advice of the technicians, reviewed the ancestral practices and carried out water damming works called *Tapes* in the Manglaralto river bed. Hence, in March and April of 2017, the JAAPMAN propitiated the immediate recharge that is reflected in the abrupt growth in Fig. 9.

This process for rescuing ancestral knowledge has been possible thanks to the use of the PAR methodology in the interactive work with JAAPMAN. Certainly, dialogues, seminars, field visits, meetings and workshops are a common strategy to agree on the appropriate measures for facing the diverse issues related to the management of the coastal aquifer. Table 3 presents the steps undertaken to carry out the PAR and facilitate decisions for the rescue of ancestral knowledge.

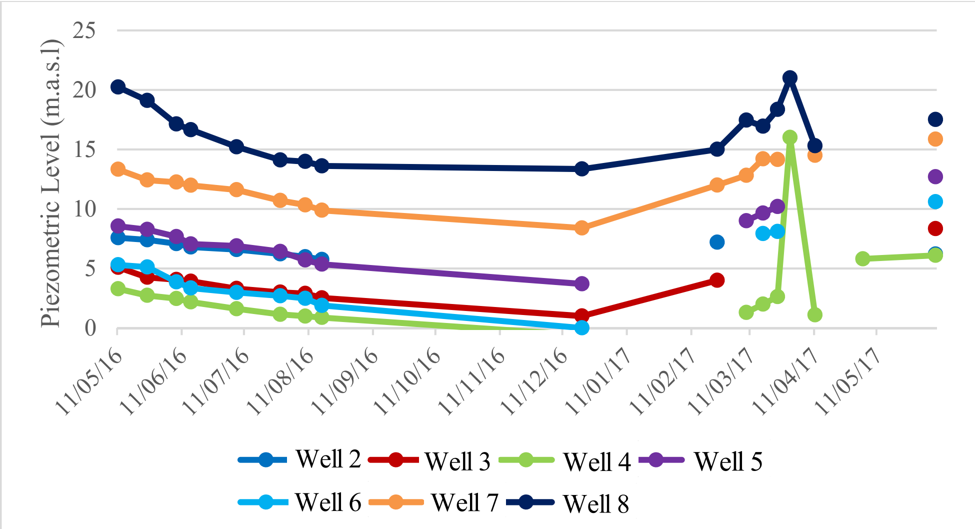

Figure 9: Variation of the piezometric level of the water extraction wells during the period 2008–2015. *(Source: Modified from [11], [13].)*

Table 3: PAR stages. *(Source: [11].)*

Activity	2006–2008	2009–2011	2012–2014
IAEA training	3	3	4
Expert technical visits	6	4	4
CIPAT-ESPOL events	6	4	5
Socializations	4	4	4
Awareness	3	6	6
Total	22	21	21

6 CONCLUSIONS

We wish to highlight the social commitment and the importance of the participatory action of a community that uses ancestral knowledge for the design and progressive evolution of the *tapes*. This occurred without the need of an engineer or a professional of the subject. *Tapes*/Dike construction is possible to the synergy of a social and technical work together.

Hence, the community of Manglaralto has applied the methodology of artificial recharge through the use of *tapes*. Currently called dikes in engineering, *tapes* are part of the ancestral knowledge of this parish. The implementation of *tapes* has been an alternative to solve the problem of growing demand and water scarcity related to climate change. Also, this has helped the JAAPMAN to solve the lack of vital liquid.

The ancestral knowledge has temporarily provided a solution to one of the main problems that PSE communities have, especially in the Manglaralto commune. We confirm the efficiency of the *tapes* and the artificial recharge is with the increase in the piezometric levels of the wells adjacent to the *tapes*. Nowadays (2018), it has four craft *tapes* and one technical-craft *tape* to help aquifers recharge (Fig. 10).

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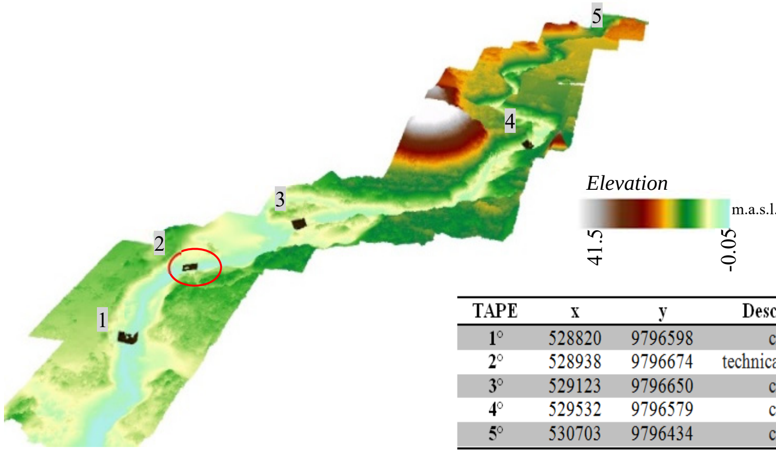

TAPE	x	y	Description
1°	528820	9796598	craft
2°	528938	9796674	technical-craft
3°	529123	9796650	craft
4°	529532	9796579	craft
5°	530703	9796434	craft

Figure 10: Location of *tapes* along Manglaralto River.

Due to the climatic dichotomy present in the Manglaralto area, where stages of excess water are experienced and others the lack of liquid contributes to the formation of quite opposite landscape units. Historically, there has been a climate characterized by a short rainy season (from January to April) and a dry season during the remaining months of the year, and the *tapes* as application of ancestral knowledge provide a solution to this reality.

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