Project summary

Aquifer storage and recovery techniques for sustainable banana production in the Magdalena region, Colombia (RECAR-BA)

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Introduction

Banana production in Colombia's Magdalena department (which accounts for 30% of the country's production) is threatened by several factors, including the scarcity of fresh water for irrigation, salinization of water and soils, and the lack of appropriate irrigation systems. These hazards lead to economic losses for farmers or even the abandonment of their land. In addition, banana production areas are located between two systems of great importance and natural and cultural capital (the Ciénaga Grande de Santa Marta and the Sierra Nevada de Santa Marta), so proper water management is essential to maintain and protect the surrounding ecosystems.

In December 2020, the Government of the Netherlands assigned the project Aquifer Storage and Recovery Techniques for Sustainable Banana Production in the Magdalena Region, Colombia (RECAR-BA) to Deltares and partner entities (IHE Delft Institute for Water Education, Wageningen Environmental Research and Fundación Herencia Ambiental Caribe), in order to contribute to its international cooperation efforts in Colombia through the Embassy of the Netherlands in Colombia, aimed at improving the sustainability of production chains in the agricultural sector. The banana marketing companies Banasan and Tecbaco-Agrovid, the banana growers' association ASBAMA, and the users' association Asoriofío have been the project counterparts in Colombia.

The objective of this project is to explore alternative water management techniques, specifically Aquifer Storage and Recovery (ASR) systems, to help improve water resource management in the Rio Frio and Rio Sevilla watersheds and advance sustainable banana (and plantain) production in the area. ASR is defined as the practice of storing water underground when there is an excess of surface water, and extracting it later when needed.

The project targets medium-sized banana producers in the Rio Frio and Rio Sevilla watersheds in the department of Magdalena. The results of this project report on the feasibility of artificial aquifer recharge techniques in the area and provide the first steps for producers to adopt them. The implementation of ASR techniques will contribute to the advancement of water management for banana crops towards a sustainable scheme, thus facilitating fair and equitable access to water for water users.

Methodology and results

In order to carry out a feasibility study of the ASR techniques, we worked on 1) a hydrogeological analysis to determine whether the ASR techniques would be technically feasible in the hydrogeological context of the basins studied, and to select potential areas for their adaptation, 2) a water balance to identify the availability of water for infiltration, 3) climate scenarios to estimate the water available in the future, 4) identification of the most appropriate techniques for the area, 5) identification of the factors that could limit their adoption, and 6) a cost-benefit analysis.

The project activities are focused on three scales of work: 1) the entire area of the Frio and Sevilla river basins and the Quaternary aquifer; 2) the banana growing area in the Frio and Sevilla river basins; and 3) the banana production farms.

An analysis of the stakeholders involved made it possible to define the most appropriate participation strategy for the different stakeholders. According to their interest and knowledge, the stakeholders participated in one or more of the following spaces: working meetings, socialization meetings or co-decision and co-design workshops. The stakeholders that participated in these spaces in addition to the project counterparts are CORPAMAG, Aguas del Magdalena, Parques Nacionales Naturales de Colombia, WWF, IDEAM, INVEMAR, Good Stuff International, AUGURA, FAO, Fundación Pro-Sierra Nevada de Santa Marta, and Servicio Geológico Colombiano, among others.

Hydrogeological Analysis, Water Balance and Future Scenarios

For the hydrogeological analysis, conceptual hydrogeological models of the study area were made. This was done at two scales; regional and farm level, based on information collected from different local institutions and, mainly, from Banasan and TECBACO-Agrovid. The data used consisted of lithological profiles, electrical tomography, groundwater levels and pumping rates in the study area. Based on this it was determined mainly:

- Presence of thick aquifers with good permeability
- Limited presence of the unconfined aquifer, with clay layers generally quite thick in the upper part. Water table quite shallow to allow shallow artificial recharge. However, some areas seem to show better connectivity with the first main aquifer layer.
- In the Aguja sector there is also a continuous layer of great thickness at relatively shallow depth, towards the east (Llanos farm and easternmost part of the Neerlandia farm), with intermediate transmissivity values.
- The natural recharge of the system is low, more accentuated towards the foothills.
- Natural interaction between the river and the aquifer is limited, due to the widespread presence of clay and other fine sediments.

The water balance was carried out based on local and satellite information. In the case of water availability, the Frio, Sevilla and Orihueca rivers, the environmental flow, and the availability of water from diffuse recharge were considered. In relation to demand, urban demand, African Palm demand, other uses and, in greater detail, water demand from banana cultivation were considered. The main conclusions of the water balance are as follows:

- Water availability in the Banana Zone is dominated by surface water from the Frio, Sevilla and, to a lesser extent, Orihueca rivers.
- Recharge from precipitation is very low in the northwest due to poor drainage and the high clay content of the soils. Recharge increases towards the southeast, particularly due to sandier soils and better drainage, especially in the foothills. Precipitation also increases towards the southeast.
- Surface water availability in the dry season is very low and insufficient to meet demand, which is high during that season. There is a structural surface water deficit of up to 68Mm3/year, so most of the farms use groundwater to cover part of the deficit. However, water availability in the wet season is higher, and in annual terms is sufficient to meet demand even in the driest years. This includes consideration of ecological flows, which means that only a percentage (20-30%) of the available water can be used to meet demand. In the Sevilla River area the

situation is more critical for surface water, as the percentage of water available to meet demand is low as a consequence of the high demand for ecological flows.

The climate change analysis was carried out using five global models and two scenarios (RCP4.5 and 8.5) and calculating the projection in three future periods (2011-2040, 2041-2070 and 2071-2100). To reduce biases, the projections were adjusted with the historical values used in the water balance analysis. The results of the analysis are as follows:

- There is a clear impact of climate change in the area, with a very consistent temperature increase forecast.
- The impact of climate change on precipitation is more uncertain, although a significant reduction is expected.
- The impact on recharge in the Zona Bananera is substantial, with a significant reduction in recharge estimated between 15% in the early part of the century, even for the least extreme climate change scenario, to the order of 70% for the worst climate change scenario at the end of the century.
- The impact of climate change on the water availability of the Rio Frio and Sevilla basins, which are the main sources of water to meet demand, can only be estimated as an indication, but also shows a clear reduction, ranging from the order of 5% in the first part of the century, 10% in the middle of the century, to the order of 25% at the end of the century, depending on the climate change scenario considered.

The conclusions of these analyses indicate that about 100% of total water needs are currently irrigated. However, there is a structural water deficit (surface water deficit), so most farms use groundwater. If groundwater is not used to make up the deficit (i.e., if the irrigation needs of the crop are not met), crop yields are estimated to be 9-30% lower. This is exacerbated during El Niño events, as there is less water available and more demand. Therefore, greater future dependence on groundwater, which is of lower quality than surface water, is expected to affect banana yields.

The ASR systems should create a zone with higher quality water in the aquifer, mainly with lower electrical conductivity and hardness than groundwater.

Most appropriate ASR techniques and evaluation of areas with potential for their application

The selection of the most appropriate ASR techniques for the area was carried out in collaboration with the counterparts in Colombia by taking into account the hydrogeology of the area, land use planning, and the perception that the counterparts have of the cultural aspects that may influence the selection. A table was constructed comparing techniques such as infiltration basins, riverbed modification, inverted drainage and deep wells.

Given the geometry of the aquifers (deep and largely confined), the space available to implement ASR techniques, the need to control infiltration and pumping rates, and the current water pumping practices; infiltration wells were determined to be the most appropriate technique.

To evaluate the areas where infiltration wells could be implemented, a methodology was followed that consists of combining two sets of criteria: (1) criteria that define the urgency of the demand for ASR, such as diffuse recharge rate, competition for resource use, cropping intensity, and depth to groundwater and (2) criteria that define the suitability of the physical characteristics of the area for ASR implementation, such as transmissivity of the aquifer, depth to the aquifer, and total thickness of aquifer layers. The criteria were defined and evaluated in stakeholder workshops, and then their evaluation was reinforced with information from the area (provided by partners and stakeholders or collected in the field). The areas evaluated were limited to the areas for which information was available.

The results show that the greatest potential for the implementation of recharge techniques is around La Aguja and Orihueca.

Based on this identification and other criteria such as accessibility, safety, representativeness of the farm, and personnel available for the operation of ASR systems, six Banasan and Tecbaco-Agrovid farms were selected for the cost-benefit and feasibility analysis. The selected farms were: Neerlandia/Los Llanos, Don Said, Sami, Beatriz-Giselle, Plantación and Manantial.

These six farms were hydrogeologically characterized in more detail. The geological profiles of the farms corroborate the feasibility of recharging aquifers by infiltration wells at specific depths. In the case of the Sami farm, its geological configuration allows the possibility of carrying out aquifer recharge by the method of infiltration ponds due to the presence of permeable material in the first layer.

Based on the above, ASR systems have a great potential to be viable in the Zona Bananera.

Cost-benefit analysis

The analysis to assess the financial feasibility of ASR techniques on the six selected farms included the analysis of CAPEX (capital investment costs) and OPEX (operating expenses) costs, and that of direct benefits (farmer benefits) and indirect benefits (reduced pressure on dry season water resources and associated ecosystems). Direct benefits to farmers include higher crop yields (9-30%) due to improved freshwater availability (quantity and quality) compared to the slightly saline groundwater that farmers currently apply during the dry season; as well as prevention of water scarcity risks during adverse climatic phenomena (drought produced by events such as El Niño). Another advantage of preventing crop stress is a reduction in the use of agrochemicals (by 10%), as healthy crops require less of these inputs compared to stressed crops.

In this CBA analysis, the costs and benefits of the measures (in this case water injection into the aquifer) are compared to the 'Business as usual - BAU' scenario (defined as the current banana production system using surface water whenever available, and groundwater, with a higher salinity than surface water, on a complementary basis during dry periods).

The CBA results show that the benefit-cost ratio (BCR) is >1 in all farms, indicating that the benefits outweigh the costs. The real net benefits (in million pesos per NPV) show positive values for the 30-years calculation period between 821 million pesos in Giselle Beatriz and 22,502 million pesos in Neerlandia / Los Llanos.

The return on investment (ROI) is positive after 5 years for all farms (between 310% and 165%) except for Giselle Beatriz and Plantación (between -21% and 0%). After 10 years the ROI is positive for all farms and varies between 430% (Don Said) and 2%

(Giselle Beatriz), and between 487% (Don Said) and 13% (Giselle Beatriz) after 15 years.

Thus, investing in groundwater recharge wells is profitable for all the selected pilots considering the banana yield obtained and the reduction of agrochemical inputs. The return on investment is more than 400% after 15 years for some farms. In addition, the investment is expected to have a positive impact on the water quality of the CGSM which, therefore, can lead to improved ecosystem services.

Identification of limiting factors

In order to understand which factors could limit the adoption and scaling up of ASR techniques, a stakeholder workshop was conducted and complemented with information obtained throughout the project. The factors were divided into technical, socio-cultural and financial. The result of the analysis indicates that the most important factors to take into account are: the quality of the water to be infiltrated, the presence of local professionals with experience in ASR techniques, the salinity of the groundwater, the existence of sacred sites, and the presence of illegal armed groups.

Recommendations regarding these limiting factors are: 1) before installing any ASR system, it is necessary to initiate a water quality study that covers a period of at least one year and includes sampling of surface and groundwater at various points, 2) evaluate the location of sacred sites in the area, 3) train local experts in the subject of ASR.

Water quality for infiltration is a limiting factor on which more information is needed. The salinity of measured groundwater is generally higher than that of surface water (i.e., the water to infiltrate is of lower mineralization) so salinity is considered to be an intermediate limiting factor. However, other surface water quality issues such as turbidity, dissolved organic carbon and dissolved metals need to be considered.

Other activities carried out within the project include the development of a work plan for the implementation of an ASR demonstration project, and the development of a conceptual demonstration of a support system to decide the suitability of implementing an EAR system at a particular site.

Recommendations and future steps

ASR systems can help make water resource management more sustainable in the Frio and Sevilla river basins, as they would allow for conjunctive use of groundwater and surface water, and would lead to the following benefits:

- Decrease pressure on the surface resource in the dry season and leave more water for other users, including nature.
- Reducing crop dependence on surface water in the dry season, thereby reducing the risk of not having enough water and the risk of crop stress
- Reduce the risk and uncertainties of declining groundwater levels, and thus availability to different users
- Increase crop yields (estimated at 10%) and growers' profits by allowing access to higher quality groundwater.

Thus, ASR techniques are recommended as a solution to avoid the loss of banana production and reduce pressure on water resources in the basin.

It is recommended that an ASR demonstration be carried out in the region. This will: 1) generate confidence on the part of potential users to adopt a technique new to the region and 2) adjust the cost-benefit analysis, thereby having accurate and local data to stimulate the adoption of the technologies.

One of the aspects that requires attention is the study of the quality of the water to be infiltrated and its effect on increasing banana yields. It is recommended that a specific study be made on the quality of the water that would infiltrate and could be recovered, and its potential effect on banana yields.

In the medium and long term, there are initiatives for efficient water use in the territory that are interesting for scaling up the implementation of ASR techniques, such as the GEF project for the conservation and recovery of the CGSM, the initiatives of the Colombia Heritage Program, among others, or those led by CORPAMAG for the banana sector and by WWF within the framework of the Water Stewardship Platform.

More information

More detailed explanations of the project activities can be found in the following documents:

- For an introduction to the project, the study area, and scales of work, the reader should refer to the Phase I report*: Updated Work Plan - Aquifer Storage and Recovery Techniques for Sustainable Banana Production in the Magdalena Region, Colombia.*

- For references to the results of the water balance and hydrogeological study (Phase II), the reader should refer to the report: *Water Quantity and Quality Analysis and Aquifer Characterization - Aquifer Storage and Recovery Techniques for Sustainable Banana Production in the Magdalena Region, Colombia.*

- For references to the results of the potential recharge zones (Phase III), the reader should refer to the report: *Potential Zones and Beneficiaries - Aquifer Storage and Recovery Techniques for Sustainable Banana Production in the Magdalena Region, Colombia.*

- For the results of the cost-benefit analysis, identification of factors affecting the implementation of an artificial aquifer recharge (ASR) system, work plan for its implementation and the conceptual demonstration of a decision support system (Phase IV), the reader should refer to the report: *Technical-economic analysis and feasibility - Aquifer storage and recovery techniques for sustainable banana production in the Magdalena region, Colombia.*