Postbus 7001
6700 CA Wageningen
Agro Business Park 65
6708 PV Wageningen

Telefoon 0317 49 15 78
Fax 0317 46 04 00

www.delphy.nl

Final report

Increasing water efficiency in Colombian palm oil production by implementing efficient irrigation systems

Worldwide Expertise for Food & Flowers

Financed by
Netherlands Enterprise Agency (RVO)

Date
7 oktober 2021

Authors
Lotte Demmink, Corné Lugtenburg, Alexander Kaune, Maria Goretti, Carlos Pérez, Tulia Delgado, Nolver Atanacio Arias Arias

Table of contents

1 Executive summary

The Netherlands imports 11% of all Colombian palm oil. Therefore, a consortium between Dutch and Colombian governmental, knowledge and private stakeholders are working on increasing the adoption of efficient irrigation and fertigation systems in the Colombian palm oil sector, funded by the Government of the Netherlands. Implementing partners, Delphy, FutureWater and Solidaridad Colombia collaborated with Cenipalma, the research organisation of Fedepalma (la Federación Nacional de Cultivadores de Palma de Aceite) from July 2021 until November 2022 in the Sevilla basin (Magdalena department) on this objective. Increasing water efficiency in the palm oil sector is required for adaptation to climate change and sustainability of the palm oil sector.

Three main limiting factors for the adoption of efficient irrigation systems were found during this study:

1. Theft of sprinklers
2. Producers are reluctant to invest making use of credits
3. Lack of knowledge on the costs of sprinkler and drip irrigation systems, especially the maintenance costs, and the time of returning the investment.

Implementing efficient irrigation systems in the Sevilla basin can save up to 67% and 72% of water when adopting sprinkler or drip irrigation, respectively. The most suitable solution for improving irrigation application uniformity, crop yield and water productivity in the oil palm plantations in the basin was found to be sprinkler irrigation. But theft of sprinklers is the main limiting factor for producers to not adopt sprinkler irrigation. Theft of drippers does not occur, which increases the suitability of drip irrigation, even though the initial investment costs are higher.

The pilot study showed that the field with surface irrigation had a lower soil moisture content and lower uniformity of soil moisture content throughout the dry season compared to the fields with sprinkler and drip irrigation, causing water stress which decreases biomass production, resulting in lower production of fruit bunches. The field with drip irrigation had a higher soil moisture content and higher uniformity of soil moisture content than the field with sprinkler irrigation, but the difference is smaller than the difference between sprinkler and drip irrigation compared to surface irrigation. The pilot trials with fertigation will continue after the project, as these results will only be seen three years after the intervention started.

The lack of knowledge on the investment and maintenance costs, and return of investment of sprinkler and drip irrigation was found to be one of the main limiting factors for adoption by producers. The cost-benefit analysis contributed to bridging this gap. Investing in drip irrigation is the most profitable option as calculated in this report. Sprinkler is also profitable, but under climate change conditions less attractive. Surface irrigation is not worthwhile, only if producers pay no or a reduced fee for their water use. Fertigation is shown to be cost-effective. An extra advantage is that you can make use of the efficient irrigation systems (drip, sprinkler) throughout the whole year. However, more research and trials need to be done at Palmar de la Sierra, for tailoring the approach and to showcase it to producers.

The future action plan includes four pillars. The first is continuing knowledge development on the use of efficient irrigation systems. Cenipalma will keep monitoring the pilot studies that were established as part of this project. Moreover, the Palmar de la Sierra experimental station of

Cenipalma is fully committed to the topic of efficient water use. Cenipalma will prosecute the research projects that are already running at this experimental station. The gained knowledge and experience are disseminated within the second pillar. The results of the pilot studies are used to quantify the benefits of efficient irrigation systems and to stimulate adoption by producers. Next to that, Cenipalma will support producers which want to implement efficient irrigation systems with technical assistance. In order to have sustainable water management in the basin as a whole, a holistic approach should be taken, which is the third pillar. Multiple actors and users of water in the basin recognize the urgency to enhance efficient use of water. Connecting strategies between the basin authority Corpamag, the irrigation district Asosevilla and the productive sectors of coffee, banana and palm oil, including the engagement of the sector organisations will be the strategy for contributing to a shared vision on the basin. When implementing efficient irrigation systems within the whole basin an implementation strategy should be defined together with Corpamag and Asosevilla, to avoid water scarce situations due to reductions of drainage flows upstream. The fourth pillar includes connecting with the local and national government, and banks, in order to tackle two of the main limiting factors: the high initial investments of efficient irrigation systems and the short payback period of loans.

2 Introduction

2.1 Project

The Sierra Nevada de Santa Marta, a UNESCO-declared Biosphere Reserve, is an isolated mountain complex encompassing approximately 17,000 km2, set apart from the Andes chain that runs through Colombia. The Sierra Nevada is the source of 36 watersheds, making it the major regional 'water factory' supplying 1.5 million inhabitants as well as vast farming areas in the surrounding plains used principally for the cultivation of banana and oil palm. The flow from the rivers of the massive mountain complex amounts to approximately 10,000 million cubic meters of water annually.

The Frio-Sevilla and Tucurinca-Aracataca river basins host key agricultural activities in the Sierra Nevada. Agricultural crops from the river basins contribute substantially to the regional gross domestic product (GDP) and employment. The specific crops are crucial for regional livelihood and food security and dominate the export portfolio of the Magdalena and Cesar region.

The Northern region is water scarce and during the dry months the region faces water scarcity. Climate predictions also show an increase in water scarcity in the near and far future, while water extractions are expected to grow. Not only water quantity but also water quality is declining. Because of this there are conflicts amongst different actors and users of this resource, including oil palm, banana and coffee growers, and the community whom consume drinking water. The decline in water quantity and quality causes decreasing productivity of oil palm production, irregular production and reduction in nutrient efficiency of oil palm plantations and declining palm oil extraction rate.

To mitigate these impacts, the palm oil sector is increasingly interested in adopting more efficient water management technologies. An assignment, funded by the Government of the Netherlands through the Partners for Water program, was carried out by a consortium of Delphy, FutureWater, Solidaridad and Cenipalma. The objective of this assignment was to stimulate and support the adoption of more efficient irrigation techniques by producers. Therefore, the limiting factors for this adoption were investigated and addressed in a feasibility study and indicative cost-benefit analysis.

2.2 Project area

The project area is located south of the departmental capital Santa Marta, spreads across five municipalities of Magdalena department: Zona Bananera, Pueblo Viejo, Aracataca and parts of Ciénaga and El Retén. The five municipalities have a combined population of 257,000 people – of which at least 145,000 live inside the project area. 53% of the people in the project area do not have their basic needs satisfied (health, education, food), which is well above the national poverty index (NBI) of 28%). The Sevilla river basin is the main focus of the feasibility study.

Oil palm plantations cover around 14% of the Sevilla River basin and are located in the downstream area of the basin (Figure 1). Smallholders have up to 20 hectares each, medium producers 20-50 hectares and large farmers may have hundreds of hectares of oil palm plantations. Oil palm producers are generally organised by palm oil mill, owned by companies in which they tend to be shareholders. Currently the water association called Asosevilla manages the water supply for the irrigated oil palm plantations. More than 90% of the producers apply surface irrigation which consists of the diversion of water, in open channels and on the ground, from the main canal of Asosevilla to the plantation and subsequent diversion to the cultivation plots. The water concession from the Sevilla River is 7 Mm^3/month. In February and March, the available water is lower than the water concession.

The Sevilla River basin has two distinctive seasons; a dry season from December to March and a wet season from April to November. In the wet season the highest rainfall occurs between August and November. The drought hazard was determined to provide a better understanding of the risk of water scarcity in the basin. The highest drought hazard was found in the lower part of the basin (in the oil palm areas).

A more elaborate description of the project area can be found in Kaune et al. (2020).

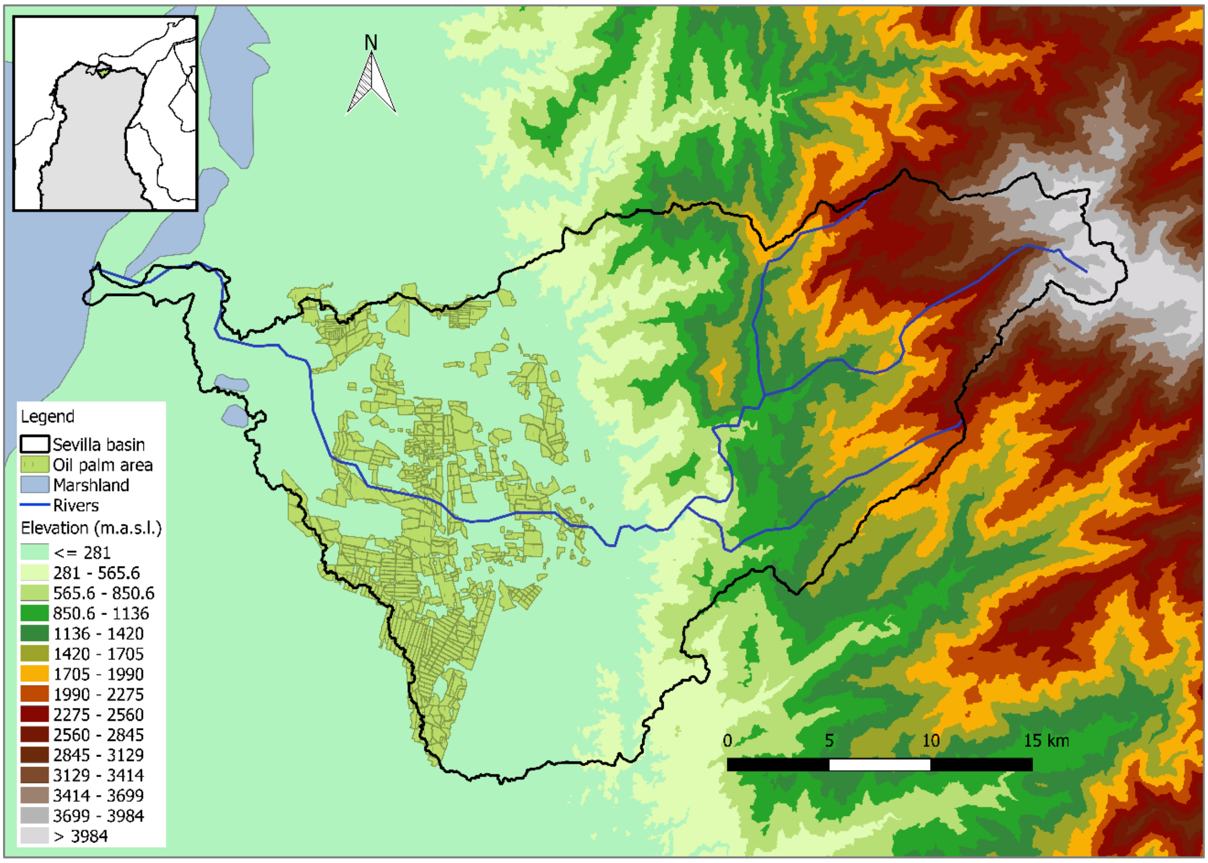

Figure 1. Oil palm area, major rivers and elevation in the Sevilla basin, Colombia (Source: SRTM, CENIPALMA). The Sevilla basin is located in the Magdalena-Cauca Macrobasin (MCMB).

2.3 Project activities

During the preparation phase of this project we have executed a baseline study; to acquire an extensive view of the basin characteristics, a questionnaire and limiting factor analysis; to gain insight into the producers' current situation, the considerations producers make and the challenges they have and their limiting factors for the adoption of efficient irrigation systems. Next to that, a SWOT analysis was executed to find the most suitable technologies for adoption by producers. Based on these activities an approach for the implementation phase and an action plan for a pilot study at three locations was developed.

Within the implementation phase three pilot studies were established and the preliminary results were analysed; an analysis of irrigation water requirements was executed to acquire insight in the effect of efficient irrigation techniques on irrigation demand in the Sevilla basin. Within a cost-benefit analysis, the investment costs and time of return were calculated for three irrigation types (surface, sprinkler and drip), as well as for combining this with fertigation technology. The results of all activities were discussed and validated during two capacity building meetings with producers and technicians and a stakeholder meeting with representatives of different water use groups.

This report provides an overview of the outcomes of all project activities, a discussion and synthesis of these results, and lastly a future action plan including recommendations.

3 Problem analysis

From the questionnaires it appeared that oil palm producers[1] are aware of the potential benefits of efficient irrigation systems. They mention that production increase, water savings, and ease of management as the most important factors why it would be interesting for them to implement an efficient irrigation system. They already experience difficulties with acquiring the right amount of water for optimal production for about one to three months per year. Producers are also aware that water availability will most probably decline in the future due to climate change. However, investing in an efficient irrigation system is not yet common.

There are multiple limiting factors which hamper the adoption of efficient irrigation systems. We have summarized the three main limiting factors, based on the limiting factor analysis[2] and after validation during the capacity building meetings:

1. Many producers who have implemented sprinkler irrigation have abandoned the technology because of theft and damage. At oil palm plantations where sprinklers were installed, these were stolen soon after establishment, which discourages the producers to re-install sprinklers and also discourages other producers to implement sprinkler irrigation. For drip irrigation this problem does not occur since drippers are hard to steal and not very valuable. The same counts for a hand-made low-tech sprinkler system, so-called plugs, which is not stolen but is less water efficient than commercial sprinkler systems (Figure 2).

2. Producers are reluctant to invest making use of credits. Palm oil plantations take three to four years after planting to start producing. Producers are able to get loans for investments but these are mostly short term loans so they have to start paying back this loan within five years, when the oil palm just starts producing fruits and thereby revenue. Next to that, the initial investment costs are high, especially for drip irrigation.

3. There is a lack of knowledge on the costs of sprinkler and drip irrigation systems, especially the maintenance costs, and the time of returning the investment.

[1] The project area includes a total of 107 oil palm plantations with a total of 8.800 hectares, forty oil plantations (with a total area of 1315 hectares) were interviewed.

[2] All identified limiting factors can be read in this report.

Figure 2. PVC plugs with flow outlets. Empiric sprinkler type developed by oil palm producers themselves. Plugs have a lower application uniformity than commercials sprinklers but since they are not stolen many producers have adopted them instead of sprinklers.

4 Overcoming the limiting factors

4.1 Technical point of view

Most suitable efficient irrigation system to be adopted
Based on the SWOT analysis, the most favorable irrigation technology to be adopted by the oil palm producers in the Sevilla River basin is sprinkler irrigation (Figure 3), specifically the wobbler sprinkler type. The analysis indicated that sprinkler irrigation in combination with water harvesting techniques such as digging planting pits and covering the soil with leaves in the edge of the pits, has the highest potential for this region. An advantage is also the availability of local capacity: local professionals do have experience and knowledge on how to design and install this type of irrigation systems.

The wobbler sprinkler type (or another similar model for agricultural applications) showed to be the most cost-effective solution for improving irrigation application uniformity, crop yield and water productivity in the oil palm plantations for this area. The required working pressure of this type of sprinkler is relatively low (10-20 meters), thus a small pump for the irrigation system is needed. This irrigation system can be easily adapted to a fertigation system by including fertilizer mixing containers and the appropriate pipeline connections and valves. The pumping system can be used with solar power if required with special security arrangements to avoid theft.

Figure 3. Sprinkler irrigation system, impact type.

However, during the capacity building meetings, theft of sprinklers appeared the main limiting factor for adoption of this system, which drastically reduces it's suitability. Theft of drip systems does not occur, which increases the suitability of these systems, even though they require a higher initial investment.

Effect of implementing efficient irrigation systems on basin level

The analysis on irrigation water requirements created insight in the effect of implementing efficient irrigation techniques on the irrigation demand in the Sevilla basin. Currently, oil palm producers mostly use surface irrigation with low field application efficiencies, approximately 25%.

The reduction in irrigation water requirements was found to be up to 67% when adopting sprinkler irrigation and 72% when adopting drip irrigation (Table 1). A reduction in irrigation water requirements means that the supply of water at the field inlet needed to satisfy crop water requirements is reduced. So, by implementing sprinkler and drip irrigation apparent water savings up to 67% and 72%, respectively, can be reached, whilst achieving equal or better crop yields.

Though, in the Sevilla basin, downstream plantations depend on the drainage flows from upstream plantations. Therefore, real water savings are much lower because of current reuse of drainage flows from one plantation to another. For sprinkler irrigation real water savings of 20% were determined. Therefore, implementing efficient irrigation systems should start with farmers located at the lower part of the basin and progressively implementing the technology upstream. In this way, water supply among oil palm producers can be secured (increasing equity in the irrigation scheme) and water availability (and quality) can be improved for other water users downstream (towns and the environment).

Table 1. Apparent water savings for change in irrigation efficiencies. The field application efficiency of the current irrigation practices (surface irrigation) is 25%.

Field application efficiency	Apparent water savings
Drip irrigation – 90%	72%
High water-efficient sprinkler irrigation – 75%	67%
Low water-efficient sprinkler irrigation – 60%	58%

Pilot study

4.1.1 Establishment of pilot study

A pilot study was executed at the experimental station of Cenipalma (Palmar de la Sierra) and at two plantations; El Reposo and San Carlos (Figure 4). The latter were selected because the owners are innovative producers, who are willing to improve their plantations. They have and will continue to function as 'lead farmers' for the region, demonstrating the established technologies to other producers.

Figure 4. The Sevilla basin (red line: border of the basin – blue line: Sevilla River) & the location of pilot study plantations(yellow).

Source: Google Earth.

The plot at Palmar de la Sierra already had a drip irrigation system, the plot at El Reposo a sprinkler irrigation system and the plot at San Carlos a low-tech sprinkler system (plugs). This enabled the pilot study to show the impact of different irrigation systems on water use. Moreover, fertigation systems, water harvesting techniques, flow meters and soil moisture content sensors were established or if already available, improved at the three locations (Table 2, Figure 5).

Table 2. Overview of technology installed at the demonstration plots as part of the pilot study.

	Palmar de la Sierra	El Reposo	San Carlos
Irrigation system	No changes	No changes	No changes
Fertigation system	Implementation	Improvement	Improvement
Water harvesting techniques	Planting pits Cover crops	Planting pits	Planting pits
Flow meter	No changes	Implementation	Implementation
Soil moisture content sensors	Implementation of RP2	Implementation of Teros 21	Implementation of Teros 21

Figure 5. Establishment of the pilot study. Left and middle: establishment of soil moisture content sensor. Right: establishment of water meter.

4.1.2 Results of pilot study

In order to analyse the results of the pilot study the tool 'IrriWatch' was used. IrriWatch uses satellite data to provide producers with daily irrigation advice, showing its data on 10x10m pixels. For the period of January – June, the data generated by IrriWatch was being analysed. This period includes the dry season, in which the irrigation advice is very useful. In this analysis, we focused on soil moisture, irrigation advice and biomass production (kg dry matter / ha), both actual (water-limited) production and potential production. We have compared three fields at Palmar de la Sierra, since these have the same soil type and an oil palm crop of the same variety and age. The fields only differ in their irrigation system (surface, sprinkler and drip irrigation).

The analysis showed that the soil moisture content in the surface irrigation plot is much lower throughout the dry season, compared to the sprinkler and drip irrigation plots. There is also a minor difference between sprinkler and drip irrigation, the latter having a higher soil moisture content. If the soil moisture content is too low, the crop suffers from water stress, causing losses of biomass production (Table 3, Figure 6). Uniformity of soil moisture content was better for drip irrigation than for sprinkler irrigation. For the surface irrigation plot, 1600 kg dry matter per hectare was lost due to water stress. For sprinkler and drip irrigation, very small production losses (5 kg dm/ha and 45 kg dm/ha, respectively) due to water stress occurred.

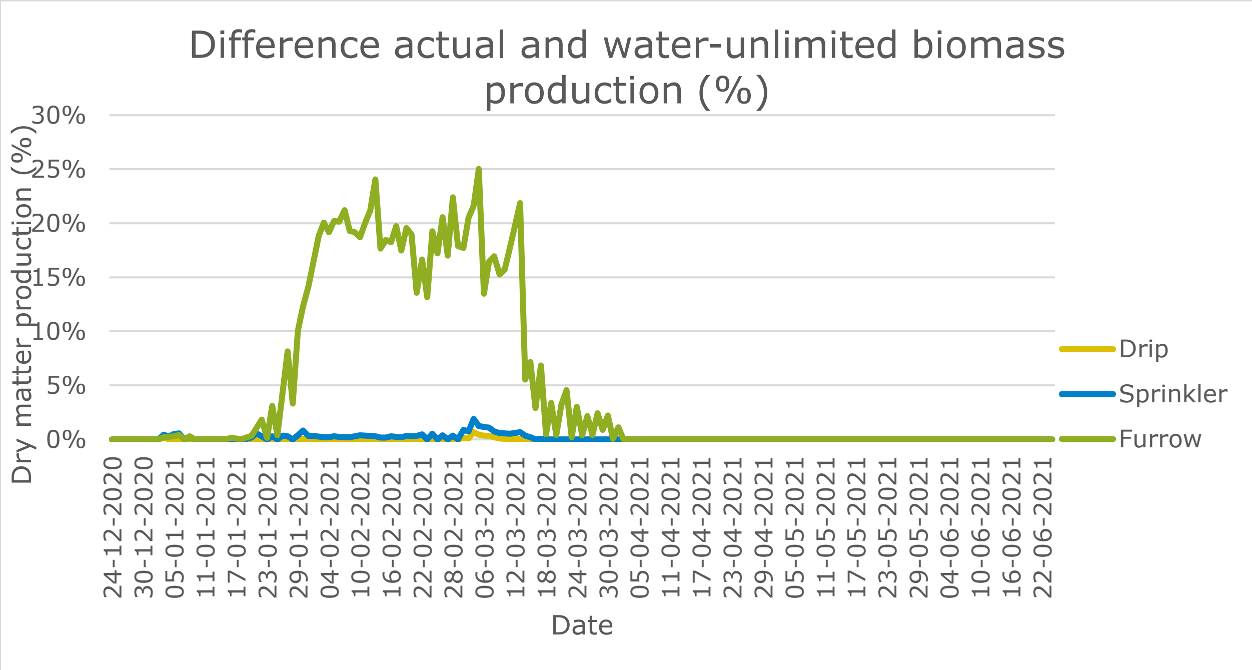

Figure 6. Difference between actual and water-unlimited biomass production (%).

Table 3. Loss in biomass production due to water stress.

	Drip	**Sprinkler**	**Surface**
Actual production (kg dm/ha)	28857,8	27603,8	25060,1
Water-unlimited production (kg dm/ha)	28863,6	27649,1	26674,9
Difference (kg dm/ha)	5,8	45,3	1614,8

So, the field with surface irrigation had a lower soil moisture content and lower uniformity of soil moisture content throughout the dry season than the fields with sprinkler and drip irrigation, causing water stress which decreases biomass production, resulting in lower production of fruit bunches. The field with drip irrigation had a higher soil moisture content and higher uniformity of soil moisture content than the field with sprinkler irrigation, but the difference is smaller than the difference between sprinkler and drip irrigation compared to surface irrigation.

4.2 Economical point of view

In the project a Cost-Benefit Analysis (CBA) was conducted to study the financial outcomes of investing in efficient irrigation technology by a farmer. Information from Cenipalma and the region was acquired for this. Six scenarios were developed, differing between the irrigation systems used and the climatic conditions. Using this scenarios, the production costs and benefits could be investigated for a palm oil plantation with a cycle of thirty years. Table 4 shows the scenarios.

Table 4. Scenarios of CBA.

Scenario	Irrigation technology	Climatic conditions
1	Surface	Current
2	Surface	Future climate
3	Sprinkler	Current
4	Sprinkler	Future climate
5	Drip	Current
6	Drip	Future climate

Table 5 shows the results of financial indicators for the six scenarios. Investing in drip irrigation is the most profitable option as calculated in this report. Sprinkler is also profitable, but under climate change conditions less attractive. Surface irrigation is not worthwhile, only if producers pay no or a reduced fee for their water use. It has been reported before that there are producers in the area who do not pay for their actual water use due to a lack of flow meters. Also, illegal water use occurs in the area (Kaune et al., 2020).

Table 5. Results of financial indicators of the six scenarios.

Scenario	Irrigation	Efficiency	Climate conditions	ROI 5 y	ROI 15 y	ROI 30 y	NPV 15 y (COP)	IRR 15 y
1	Surface	50%	Current	-3,69	-1,72	1,72	- 152.485.087,68	-9,06%
2	Surface	50%	Climate	-4,18	-5,01	-5,81	- 277.205.978,71	Negative
3	Sprinkler	75%	Current	-1,78	3,42	11,78	135.912.491,91	7,09%
4	Sprinkler	75%	Climate	-1,97	2,13	8,82	37.591.214,74	3,62%
5	Drip	90%	Current	-1,64	4,30	13,79	212.238.107,85	9,24%
6	Drip	90%	Climate	-1,83	2,96	10,71	106.544.020,01	5,96%

The investment in drip irrigation is higher, thus requires more money from the producer who is willing to invest. This can also be a bottleneck, as loans might be hard to get and the payback period is short. Having the financial tool, can help producers and banks getting insight in the financial risks related to this investment.

Fertigation is shown to be cost-effective. An extra advantage is that you can make use of the efficient irrigation systems (drip, sprinkler) throughout the whole year. However, more research and trials need to be done at Palmar de la Sierra, for tailoring the approach and to showcase it to producers.

Climate change will make palm oil cultivation less profitable regardless of the type of irrigation system installed, but sprinkler and drip make it possible to still have a livelihood from palm oil production, while saving water. This is extra important for the whole basin. Water becoming more scarce, and having pressurized systems also prioritized in water distribution.

Increasing the payback period from five to ten years is making the investment less profitable in the end, but it reduces the negative cash balance during the initial years. This can make it easier for producers to invest in these technologies, as their cash requirement during these years is lower.

4.3 Social point of view

Validation and discussion of results

Capacity building meetings were held to discuss the results of the project's activities with producers and technicians. The meetings focussed on three topics: efficient irrigation systems, fertigation and business management. Within the first part on irrigation, the results of the analysis on irrigation water requirements, and the (dis-)advantages of multiple irrigation systems were shared. Moreover, the performance of the irrigation systems within the pilot studies were compared, using the outcomes of IrriWatch. The principles and implications of implementing fertigation were introduced during the second part. The outcomes of the cost-benefit analysis for implementing surface, sprinkler and drip irrigation were discussed and validated by the producers and technicians during the third part. The theoretical part was strengthened by visiting the pilot studies. These visits were very useful for the participants to get a better understanding of the theory. Next to that, the limiting factors identified within the limiting factors analysis were discussed. From these discussions, the importance of theft of sprinklers as the main limiting factor for adoption of sprinkler irrigation was stressed. Also, additional limiting factors were identified such as the importance of a suitable financing scheme and a stable electricity connection when implementing efficient irrigation systems, especially for drip irrigation. Which could be overcome by using alternatives for generating energy such as solar power.

The capacity building meetings were also used to create awareness amongst producers and technicians on the necessity of adopting efficient irrigation systems and its relation to sustainable water management on basin level. During the limiting factor analysis it appeared that producers already are aware of the potential benefits of efficient irrigation systems for their own plantation but are less aware of the effect on basin level. The benefits on farm level were quantified within the cost-benefit analysis, the benefits on basin level within the analysis on irrigation water requirements. The results were discussed to stress the benefits on both levels.

Figure 7. Julián Monroy of Cenipalma presenting the pilot study at the Experimental station of Cenipalma; Palmar de la Sierra.

Sustainable water management in the basin as a whole

A meeting with multiple actors and users[3] of the water in the Sevilla River basin was held to understand different point of views from the main local stakeholders that are also related to the basin and surroundings.

Participants shared their main concerns regarding the use of water in Magdalena. Culture in water management is identified as the source of the inefficient use. People do not have a shared vision of the river basin, so they do not calculate the real needs and they do not always understand that their actions could affect their neighbours. The legality of water concessions is a challenge to keep an equitable distribution of the natural resource in the area. Deforestation along the river basin is also a concern as it is necessary to protect the riparian area to be more resilient against floods and dry seasons.

In some cases, oil palm producers have badly implemented alternative irrigation systems, sometimes with bad design and quality, which do not work correctly. These bad examples have generated

[3] The meeting includes 33 attendees representing the local government (Corpamag and Gobernación de Magdalena), civil society (FAO, Herencia Ambiental, Deltares), coffee (CIPAV), bananas (Augura, Asbama, Daabon) and palm oil (Cenipalma, El Roble, Aceites S.A., Palmaceite S.A., Daabon) sectors.

stigmas in producers of the area which are demotivated because they believe irrigation systems are useless.

It is interesting to realize that even if participants represent different economic activities, all of them are facing similar challenges and recognize the urgency to enhance an efficient use of water in the Sevilla River Basin. Working together to raise awareness among local users is identified as the option with the highest potential to face the problem.

Common ideas to increase the collaboration around the efficient use of water in Magdalena were shared by the representatives of the participant organizations, providing constructing feedback according to their influence and relevant expertise in the area:

- Achieve integrated management with a sustainability approach leaded by government institutions (Corpamag, Gobernación de Magdalena, Irrigation Districts) in concordance with the sector organisations (Fedepalma, Asbama, Augura, Fedecafé) and the communities.

- Scale the implementation of efficient irrigation systems (drip and sprinkler) which have already demonstrated savings in the use of water. It also includes the maintenance of drainage and irrigation channels in poor conditions.

- Communicate results of implemented better practices and develop trainings to sensitize communities (including farmers) about the rational use of water.

- Promote activities and a scheme of incentives to conservating forests and riparian area along the river basins.

5 Future action plan

5.1 Knowledge development

To continue contributing to the knowledge development on efficient water management in the oil palm sector, a research project on fertigation was started at the Palmar de la Sierra Experimental Station, as part of this project. The main objective is to increase nutrient use efficiency by adjusting tools for the nutrient management of oil palm under a fertigation system. For this, firstly, the technical management plan and monitoring will be established according to the conditions of the crop. Secondly, fertilizer doses will be selected according to the phenological state of the crop. Third, the impact of technology on the development and production of the crop will be quantified, and finally, the management and operation costs of the fertigation system for oil palm cultivation will be assessed.

Cenipalma is also carrying out other research projects at the experimental station, which are focused, on the one hand, on the determining the water requirements of the crop in different phenological stages both in Elaeis guineensis and hybrid OXG cultivars. On the other hand, the hydraulic and operational performance of multiple irrigation systems (surface, sprinkler and drip) and the response of the palm cultivation under each irrigation method are being evaluated. Cenipalma will continue monitoring the pilot studies at the two lead farmers and at Palmar de la Sierra to gather reliable research results. Additionally, in another study, the assessment of the benefits of plant cover and application of organic matter (empty fruit bunch and leaves) as practices for conserving soil moisture is being carried out for the northern zone of Colombia.

5.2 Knowledge transfer

For the establishment of knowledge transfer strategies on efficient water management in oil palm, it is essential to continue with the follow-up of the pilot areas so that the producers and technicians see the benefits in the field of establishing efficient irrigation systems, such as an increase in crop productivity and water savings.

For that, monthly visits will be made by extension officers of Cenipalma to the lead farmers, mainly in the dry season. Assistance will be provided to the technicians during irrigation programming, according to the soil moisture monitoring through the sensors installed in the field and the water balance method. Likewise, they will be guided in using wate, pH and electrical conductivity meters during fertigation. In this way, the producers will understand their usefulness and how these practices achieve considerable savings in water and fertilizer. Additionally, the producers will be taught on using organic residues and cover crops, and the establishment of planting pits to contribute to soil moisture conservation. Finally, to quantify the impact of these technologies, the crop production will be monitored for two years, considering that they are mature palms of more than eight years old.

As mentioned above, the pilot studies will be monitored to show the producers the benefits of the technologies implemented in the project. Cenipalma will support the producers in becoming lead farmers, following the lead farmers approach or the 'producer to producer' knowledge transfer

strategy, as it is called by Cenipalma. This strategy has been widely used by Cenipalma's extension team due to its positive impact on the adoption of technologies. In this case, Cenipalma will stimulate the producers of the pilot studies to actively disseminate the gained knowledge and experience to neigbouring producers. For this, tours and field days will be scheduled, to show other producers the implemented technologies in the field. In addition, workshops and courses will be held to share the results of water management studies and on efficient irrigation systems.
Finally, it is proposed to spread the results in scientific and extension events in the different palm regions of the country; an example of this is the national technical meeting of oil palm and the international conference.

It is important to note that parallel to this strategy, Cenipalma also developed a plan that aims to increase water efficiency in plantations. For this, it has been establishing pilot farms such as the pilot studies at San Carlos and El Reposo, where the best agronomic practices that contribute to this rational use of water are carried out.

Figure 8. Julián Monroy of Cenipalma presenting the pilot study at the Experimental station of Cenipalma; Palmar de la Sierra.

On the other hand, in order to strengthen and guarantee the technical assistance and technology transfer service to all oil palm producers, in the Palm Oil Congress held in 2019, it was established that 10% of the palm development fund is destined for this activity and from 2022 it will increase to 20%. To achieve this goal, Cenipalma's extension department developed the technical assistance guidelines for the palm union. The specific objectives of this strategy are:

1. The application of site-specific assistance to producers.

2. Modernize communication and information systems to promote interaction between producers, oil palm mills, extension services, Fedepalma and Cenipalma.
3. Define the socioeconomic, cultural, and productive profile of producers to identify their needs effectively.
4. Construct strategic and operational plans to close productive, environmental, and social gaps to achieve sustainable palm oil production.

These action plans include the efficient use of water in the crop, in which the implementation of efficient irrigation is a fundamental component, and its use will continue to be promoted, considering the socio-economic conditions of the producers. The implementation of efficient irrigation systems should be considered on basin level, which can be read in pillar three; implementation strategy for the whole basin.

In addition to this strategy, it should be noted that the Sanitary Management Coordination of Cenipalma and Fedepalma have been facilitating for special loans to encourage palm growers to use efficient irrigation systems. Due to the Bud Rot disease, many producers are renewing their plantations with a new resistant hybrid variety (named OxG). This provides the opportunity to invest in efficient irrigation systems, as investing during the start of the cultivation is most efficient. These special loans allow producers to invest in these irrigation systems.

5.3 Basin management approach

Connecting with the basin management strategy

The Watershed Ordinance and Management Plan (POMCA) is a territorial planning instrument, developed by the regional environmental authorities in Colombia. For the Sevilla river basin, CORPAMAG is developing the formulation process. In addition to its importance as for decision-making tool for the future management of the water resource, it is relevant for the participatory process involved to build it, including actors of the basin in the analysis of the current situation and future scenarios.

Therefore, this process is fundamental for the construction of a shared vision of the basin, necessary for palm producers, among other productive activities in order to recognize future scenarios in terms of water availability and consequently, the definition and coordination of alternatives for its conservation and efficient use, in conjunction with the regional environmental authority (CORPAMAG) and the irrigation district (Asosevilla).

In addition, there is a particular planning instrument, defined by the Decree 1090 of 2018, PUEAA (Program for the Efficient Use and Saving of Water), focused on optimizing the use of water resources. It must define projects and actions to be adopted by water users, specifically who request the concession of waters. Although this instrument is currently mandatory for the irrigation district, it is recognized as needed to coordinate its formulation and implementation with the different oil palm plantations, in particular for more efficient irrigation systems.

Currently an agreement between Cenipalma and Corpamag is in progress. Their main objectives include: a) promote water governance among users of water resources, b) coordinate efforts for the conservation of biodiversity and ecosystem services and c) develop actions for adaptation to climate change. Consequently, this is an opportunity to disseminate initiatives and good practices to the oil palm sector. The oil palm plantations and companies will receive technical support from the Environmental Authority in order to guide and facilitate its environmental management.

This initiative can provide support in order to build awareness among producers. As Corpamag and Cenipalma share information about the conditions of the Sevilla river basin, it can contribute to promote a basin vision and particularly, take actions from the productive activities.

Connecting with stakeholders and water users in the basin

Collaborative work will continue to be the key to ensure a basin management approach. With the support of local partners of the project, Cenipalma and Solidaridad, we will disseminate the results of the intervention with stakeholders and water users. Connecting strategies between the basin authority Corpamag, the irrigation district Asosevilla and the productive sectors of coffee, banana and palm oil, including the engagement of the sector organisations (Fedepalma, Cenipalma, Augura, Asbama and Fedecafe) will be the strategy for contributing to a shared vision of the river basin.

Implementation strategy for the whole basin

Currently, the traditional surface irrigation technique used in the oil palm plantations in the Sevilla basin require high volumes of irrigation water (8253 m^3/ha/month) due to its low irrigation application efficiency (25% - 50%). Low irrigation application efficiencies lead to uncontrolled water flows (drainage flows that return to streams and potentially reused) which may affect water quality for downstream users such as towns (drinking water) and the environment. Certainly, this is a threat to public health and the sustainability of the basin, which has motivated the adoption of efficient irrigation (such as sprinkler or drip) to reduce these drainage flows. However, part of these drainage flows is currently also reused by tail end (downstream) producers. Hence, producers adopting drip or sprinkler irrigation upstream may pose a threat to producers in the tail end of the district. These producers (tail end producers) would need to change their current water management practices and adopt efficient irrigation technologies too, to avoid water scarce situations due to the reduction of drainage flows upstream. A solution is to progressively adopt irrigation technologies starting with producers located at the lower part of the basin (or tail end of the irrigation district). In this way, water supply among oil palm producers can be secured (increasing equity in the irrigation district) and water availability (and quality) can be improved for other water users downstream (towns and the environment).

The viability of the proposed solution has to be further evaluated together with the basin authority (Corpamag) and the irrigation district (Asosevilla). A future action plan consist in developing several scenarios on how and where to implement irrigation technologies in the basin to avoid water scarce situations due to reduction of drainage flows upstream. This scenario analysis can be done by using water allocation tools. The basin authorities and the irrigation districts which are in charge of managing the water resources in the Sevilla basin and neighbouring basins require agile water allocation tools for decision-making. These tools and corresponding digital platforms should allow them to access and view up-to-date information on the availability, demand and use of water. Hence, displaying real-time information (e.g. meteorological, hydrological, groundwater, water quality, satellite monitoring), forecasts, drought indicators, maps, as well as information on the local hydrological system. The HERMANA tool[4] provides such information to support water resources management at basin level. This tool has been successfully introduced through PvW Programme two years ago, and now is being used by several Regional Corporations (Corporaciones Regionales) such as the CVC (Valle del Cauca) in Colombia. Additionally, Regional Corporations in the North of

[4] https://www.hermana-colombia.co/

Colombia (or basin/water authorities) could benefit from this tool, especially because in this region climate predictions estimate a high reduction in rainfall in the near future.

5.4 Empowering policies

The fourth pillar includes connecting with the local and national government, and banks. One of the main limiting factors for adoption by producers is the short payback period of loans. Currently, the payback period at most banks is five years. However, a new palm oil crop only starts producing fruit bunches after four to five years, so within five years a producer does not have enough revenue yet to pay back the loan. Fedepalma could discuss possibilities with banks to prolong the payback period of loans. Moreover, banks with digital credits are entering the Colombian market which could provide financial benefits when getting a loan. Another important limiting factor is the high initial investment costs of efficient irrigation systems. It would be very promising if the local or national government could provide a subsidy, which could spread or reimburse part of the investment costs. Again, Fedepalma could take the initiative in discussing possibilities.

As an example, the Sanitary Management Coordination and Fedepalma have been working on the creation of credit lines for the installation of efficient irrigation systems. It is also elaborating on an environmental agenda between Magdalena Regional Autonomous Corporation (CORPAMAG), Fedepalma, and Cenipalma to strengthen the environmental authority, improving the environmental management of the oil palm sector and promoting the sustainability of environmental goods and services based on the comprehensive management of water resources. Among the activities proposed in the agreement are the design and implementation of a mechanism to legalize environmental permits of water collection, as well as the adjustment of procedures for producers to get the permits and expedite their issuance efficiently, optimization of the current irrigations systems in plantations and carrying out a concerted regulation of the water resource according to the time of year.