SWOT analysis for efficient irrigation of oil palm in the Sevilla basin, Colombia

REPORT 219

CLIENT RVO

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SWOT Analysis Report

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Summary

This SWOT analysis is part of a feasibility study on the adoption of more efficient irrigation techniques by oil palm farmers in Colombia. The SWOT analysis includes the evaluation of the potential of efficient irrigation, fertigation and water harvesting techniques to be implemented in the oil palm farms in the Sevilla basin in the northeast of Colombia.

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1 Introduction

1.1 Background

The Sierra Nevada de Santa Marta, a UNESCO-declared Biosphere Reserve, is an isolated mountain complex encompassing approximately 17,000 km^2, set apart from the Andes chain that runs through Colombia. The Sierra Nevada has the world's highest coastal peak (5,775 m above sea level), just 42 kilometres from the Caribbean coast. The Sierra Nevada is a landscape of biological juxtapositions. Palms, cacti and tropical dry forest fringe the park's northern border along the Caribbean coast, while tropical rain forests, treeless plains, and snow-capped peaks are found in the interior. The mountain's isolation has allowed for many plant and animal species found nowhere else on Earth. The Sierra Nevada is considered a precious natural barrier that avoids the passing of Caribbean hurricanes in 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 the major agricultural activities in the Sierra Nevada. Agricultural crops from the river basins contribute substantially to the regional GDP and employment. The specific crops are crucial for regional food security and dominate the export portfolio of the Magdalena and Cesar region.

Key issues that the region is facing in the basins from rivers originating in the Sierra Nevada, are:

- Declining availability of water for irrigation of plantations;
- Declining availability and quality of water for human consumption;
- Increasing salinization of groundwater and soils;
- Increasing incidence of floods.

These issues generate a number of negative impacts:

- Declining productivity of oil palm plantations;
- Declining palm oil extraction rate;
- Flood damage to crops, infrastructure and homes;
- Water contamination and receding groundwater threatening drinking water availability;
- Decreasing soil quality due to salinization.

To mitigate these impacts, the palm oil sector is increasingly interested in adopting more efficient water management technologies. A feasibility study is being carried out by a consortium of Delphy, Solidaridad, Cenipalma and FutureWater. The **objective of this feasibility study** is to characterize the local environment at basin scale and current cultivation practices and assess the feasibility of possible interventions regarding efficient irrigation, fertigation and water harvesting in oil palm areas.

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%)[1]. The Sevilla river basin is the main focus of the feasibility study.

[1] Poverty index refers to the indication developed by United Nations which assesses three elements:

- Longevity, which is defined as the probability of not surviving to the age of 40.

1.2 This SWOT analysis

The **objective of this SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis** is to obtain insights of the potential of irrigation technologies and water harvesting techniques to be implemented in the oil palm farms in the Sevilla basin, Colombia. The results of the SWOT analysis will be used as a basis to select the appropriate technology, develop an approach to address the limiting factors and the action plan to set up a pilot project.

2 Method

To assess the potential of a solution or approach, a SWOT (**Strengths, Weaknesses, Opportunities and Threats)** analysis can be performed. The SWOT analysis technique is typically used as a tool to gather, synthesize and analyse information in feasibility and scoping studies (Bekchanov et al., 2010; Dubey, 2012).

For the oil palm farms in the Sevilla basin (Colombia), a baseline assessment, questionnaires, a limiting factor analysis, and a literature review were undertaken for the SWOT analysis to determine the potential for adoption of irrigation technologies such as sprinkler irrigation, drip irrigation, fertigation, and water harvesting techniques (Figure 1). Different types of technologies and techniques were evaluated specifically for the local context with the support of local expert knowledge.

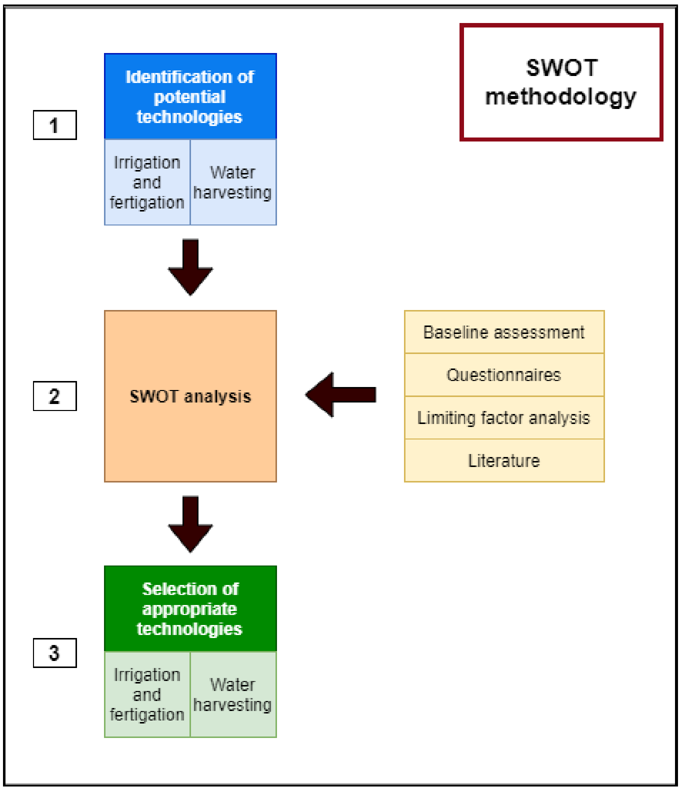

Figure 1. SWOT methodology applied to the project on irrigation technologies and water harvesting techniques in oil palm farms in the Sevilla basin, Colombia.

- Knowledge, which is assessed by looking at the adult literacy rate.
- A 'decent' standard of living (% of the population not using an improved water source and % of children under-weight for their age).

Advantages and disadvantages of each technology and techniques were defined as strengths and weaknesses were identified that influence their attractiveness. Additionally, the stimulus to implement the technology and its potential benefits were defined as possible opportunities, while threats were defined as the barriers in adopting the methods and its potential negative consequences. The effect of each technology and technique on identified strengths, weaknesses, opportunities, and threats is evaluated with a score from 3 to 1 (3=High, 2=Medium, 1=Low, N=Not apply). The effect of using each technology is measured against the use of the traditional surface irrigation method. The effect of using water harvesting techniques is measured against the lack of use of these techniques.

3 Options for irrigation technologies and water harvesting techniques

Based on the baseline assessment, questionnaires and the limiting factors analysis, a list of options was prepared for irrigation technologies and water harvesting techniques. Table 1 shows specific types of technologies and techniques that were considered candidate technologies given the local context.

Currently farmers already apply several irrigation technologies and water harvesting techniques. Examples are mulching (recycled leaves as soil cover to reduce evaporation), excavation of planting pits to increase infiltration, and sowing of legumes to retain runoff. Selected farmers have adopted sprinkler type systems. For example, the use of the wobbler sprinkler type (e.g. Mini-Wobbler from Senninger), or the impact sprinkler type (e.g. Netafim 2450), which provide better irrigation application uniformity compared to the traditional surface irrigation method potentially leading to higher water productivity. The wobbler sprinkler type is preferred among farmers due to costs. However, the use of an empiric sprinkler type called “PVC plug with flow outlets”, has been adopted by some oil palm farmers to reduce costs and theft risk, with the disadvantage of reduced application uniformity.

The cost of the sprinklers or drippers and the cost of associated equipment (pumps, pipelines and valves) necessary for the adequate operation and maintenance is an important factor, including also the theft risk after the system is installed. A cost-effective and safe option should motivate more oil palm farmers to adopt this type of technologies and techniques in the basin. This will help in preventing water deficit and fertilizer loss to potentially increase crop yields and water productivity (Kaune et al., 2020).

Table 1. Identification and evaluation of potential irrigation technologies and water harvesting techniques, including specific types considering the local context (Oil palm farms in the Sevilla basin, Colombia). Results are supported by the baseline assessment, questionnaires and limiting factors analysis developed in this feasibility study with support of local expert knowledge.

Sprinkler irrigation	**Drip irrigation and alternative surface irrigation**	**Water harvesting techniques**
PVC plug with flow outlets:  Empiric sprinkler type developed by oil palm farmers (water pump needed). Two flow outlets or four flow outlets are used.	Self-compensating dripper:  Filtration of water is required. Little number of farmers use this technic. Although it applies the water directly to the roots, the relative high costs and chances of emitters being stolen limits the use.	Mulching:  Soil cover for reducing evaporation (currently recycled leaves are being used to cover the soil at the edge of the planting pit).

Wobbler type (Mini-Wobbler):  Operation pressure of 10-20 meters head (water pump needed). Diameter coverage of irrigated water is 10 meters. More use by farmers than the impact type sprinkler.	Hose, high flow application (no dripper):  Little number of farmers use this technic. Relative high costs. Without drippers the application efficiency is reduced.	Planting pits:  In-situ technique to increase infiltration and prevent evaporation (currently pits are excavated around the stem of the crop). Roots are superficial (max root depth is 0.6 meters).
Impact type (Netafim 2450):  Operation pressure of 10-20 meters head (water pump needed). Diameter coverage of irrigated water is 12 meters. Higher cost than Wobbler type.	Surface irrigation through windows:  This is an alternative surface irrigation to the traditional surface irrigation. A movable pipeline is connected to a water source. The pipeline has openings ("windows") which can be directed to the planting pit for irrigation. Limited use.	Vegetative strips:  Strips of vegetation on contour lines (technique to retain runoff). The sowing of legumes as cover is carried out throughout the field area, with materials such as kudzu, desmodium, mucuna.
Fertigation (using sprinkler):  The containers include the appropriate combination of fertilizers which are mixed in the irrigated water.	Fertigation (using drip):  The containers include the appropriate combination of fertilizers which are mixed in the irrigated water. A filter is needed to avoid clogging in drippers.	Rooftops and reservoir water storage:  Use the existing rooftops of pumping stations to collect rainwater in the wet season and to store it for the dry season. Also, reservoirs can be used to store water (e.g. "Finca El Cuatro").

4 SWOT analysis

A SWOT analysis was developed to determine the potential adoption of irrigation technologies in oil palm farms in the Sevilla basin. Irrigation technologies include sprinkler irrigation and drip irrigation, which are evaluated to be used instead of the traditional method of surface irrigation (also called flood irrigation). In addition, water harvesting techniques were evaluated to complement the potential use of sprinkler or drip irrigation.

The results of the SWOT analysis are summarized in Table 2, Table 3, Table 4 and Table 5. Strengths, weaknesses, opportunities and threats were identified from the baseline assessment, questionnaires and limiting factors analysis developed in this feasibility study with support of local expert knowledge. In Table 2, a first analysis is presented for the potential adoption of each irrigation technology and water harvesting techniques. In Table 3, Table 4 and Table 5, a second analysis is presented for specific types of technologies and techniques as identified in Table 1 (e.g. PVC plug with flow outlets, wobbler type sprinkler, etc).

The main strength (advantage) of sprinkler and drip irrigation is that the irrigation application uniformity in the field is improved (relative to the traditional surface irrigation method). The water will reach the rootzone directly, especially with drip irrigation. The strengths of fertigation (drip irrigation combined with fertilizers) are larger compared to sprinkler and standalone drip irrigation, as fertilizers can be applied together with the irrigation water, reaching the rootzone directly for appropriate crop growth. The benefit for the farmer is that crop yields will be increased, thanks to increased crop transpiration and reduced soil evaporation. Water harvesting techniques such as mulching, and vegetation strips can also reduce soil evaporation and optimize crop transpiration. Part of these water harvesting techniques have been already adopted by most of the oil palm farmers (see Table 1). For example, the palm leaf is used without the petiole (thorny part) scattered or located on the edge of the planting pit, and residues from the oil extraction process ("raquis") are incorporated in the soil as a source of nutrients.

The weaknesses of the proposed solution are attributed to the initial investment costs, and maintenance and operation costs associated to sprinkler and drip irrigation. For example, according to the baseline assessment, the initial investment costs for drip and sprinkler irrigation are two times higher than the cost of surface irrigation. The operation costs are increased with drip and sprinkler irrigation compared to surface irrigation when considering energy costs, however, labour costs decrease significantly (three times less). Another factor to consider is the risk of clogging of emitters. This risk is higher for drip irrigation. This depends on the quality of the irrigation water used, but also on the growth of the roots which can clog the emitters on the ground. Therefore, it is key to use filters at the water pumping station and use special drippers to repel the roots from growing into the emitters (Schifris et al., 2015).

The opportunities and threats were determined according to the attributes of the oil palm farms in the Sevilla basin. According to the baseline assessment in the Sevilla basin an increasing number of oil palm farmers have been using irrigation technologies (e.g. sprinkler irrigation) which provides an opportunity to explore further adoption of these technologies and efficient water management. Current incentive for farmers is that in times of water scarcity, the irrigation authority (Asosevilla) prioritizes water supply to those oil palm farmers using sprinkler or drip irrigation. Specifically, farmers prefer using PVC plugs with flow outlets as an empiric sprinkler type as this is a cost-effective solution and it is not easily stolen. In addition, in Colombia, river basin management plans are being developed by regional environmental authorities such as CORPAMAG (responsible for the Sevilla basin), which are committed to support water management initiatives to improve water availability and quality at basin level. In the northeast of Colombia, it is especially important to support actions to improve water management and fertilizer use in agriculture such as in the oil palm farms. This is an important incentive for continuing testing and potentially upscaling irrigation technologies which can increase crop yields and contribute to economic growth.

A key opportunity for improvement is the incorporation of a water fee charged by measured water volume. Currently the water use in the fields is not being measured. The water use is being charged using a preestablished water supply rate per hectare. The adoption of pressurized irrigation systems (e.g. drip or sprinkler irrigation) can include measuring equipment that can record the water volumes used. This can help in keeping track of the water used and support better decisions on water allocation. In addition, it is key to obtain the crop water requirements, which is the water consumed by the crop to sustain adequate crop yields (Steduto et al., 2012). In this way the water used by the farmer can be compared against the crop water required for determining if too much or too little irrigation is applied. The plan of this study at a later stage is to determine crop water requirements through remote sensing techniques (Hunink, 2012) for all the oil palm farms in the Sevilla basin. Also, developing soil moisture measurements in selected oil palm farms.

Another factor to consider is the pollution to groundwater and surface water (such as the river). This pollution can be reduced as water flows from the fields can be better controlled with irrigation technologies. Currently, surface irrigation leads to uncontrolled water flows (drainage flows) which may include high concentrations of agrochemicals reaching downstream water users such as cities (drinking water) or the environment. Certainly, this is a concern to public health and the sustainability of the system. However, part of these water flows are also reused by other farmers, thus adopting drip or sprinkler irrigation upstream may pose a threat to farmers in the tail end of the irrigation district (Kaune et al., 2020). These farmers would need to change their current water management practices and adopt irrigation technologies to avoid water scarce situations. Another threat for sustainable oil palm production with the adoption of drip or sprinkler irrigation is the uncontrolled expansion of oil palm areas. Once the farmer has changed his technology to drip or sprinkler irrigation the crop yield will increase. Given the investments and income, farmers would like to increase the area of production which could be a threat to the environment. However, currently buffer zones for environmental protection exist in the region (AVC), which limits the expansion of production areas. This is also an opportunity to concentrate efforts in the existing oil palm areas and improve water productivity. This means improving the productivity of current irrigated areas avoiding potential environmental impacts of additional production areas (either with oil palm or any other crop such as banana).

Table 2. SWOT analysis for adopting different irrigation technologies and water harvesting techniques in oil palm farms in the Sevilla basin, Colombia. The effect of using each irrigation technology (sprinkler or drip) is measured against the use of the traditional surface irrigation method. The effect of using water harvesting techniques is measured against the lack of use of these techniques. The different strengths, weaknesses, opportunities and threats were identified according to the baseline assessment, questionnaires and limiting factors analysis developed in this feasibility study with support of local expert knowledge.

	Effect on strengths and opportunities (3=High, 2=Medium, 1=Low, N=Not apply)				*Effect on weaknesses and threats (3=High, 2=Medium, 1=Low, N=Not apply)*		
Strengths (Advantages)	*Sprinkler irrigation*	*Drip irrigation*	*Water harvesting*	***Weaknesses (Disadvantages)***	*Sprinkler irrigation*	*Drip irrigation*	*Water harvesting*
Increases crop yield	2	2	1	Requires initial investment cost	3	2	1
Increases labor productivity	3	2	1	Requires skilled labor	2	2	1
Decreases disease risk	3	2	1	Requires additional O&M budget	3	3	1
Increases water application uniformity	3	3	N	Requires a level of water quality	2	3	N
Field water savings	3	3	N	Waste of materials	1	1	N
Minimizes fertilizer loss	2	2	2	Risk of clogging of emitters	2	3	N
Reduces soil evaporation	2	3	3	Water pumping costs	3	2	N
Opportunities (Incentives)	*Sprinkler irrigation*	*Drip irrigation*	*Water harvesting*	***Threats (Constraints)***	*Sprinkler irrigation*	*Drip irrigation*	*Water harvesting*

Contributes to economic growth by increasing yields	3	2	1	Under-development of market supply	2	2	N
Possibility of introducing water fee per volume of water used per farm	3	3	N	Theft of materials and equipment	3	3	N
More time available for other activities	2	2	N	Cultural constraints on adequate water management	3	3	3
Less pollution of groundwater and surface water downstream	2	2	1	Inaccurate communication between water management institutions	3	3	3
Reduction of water fee for implementing technology	3	3	N	Lack of willingness of farmers to improve productivity	3	3	3
Increased experience of using solar energy for water pumping	3	3	N	Risk of water not being available for downstream users due to reduction of drainage flows	2	3	1
Strengthen rules for limiting expansion of oil palm areas in order to obtain sustainable water savings	3	3	1	Risk of not achieving sustainable water savings as oil palm areas might increase	3	3	1
Irrigation water supply priority in times of water scarcity				Risk of oil palm area being replaced by banana area.	1	1	1

Table 3. SWOT analysis for adopting different sprinkler irrigation types and fertigation in oil palm farms in the Sevilla basin, Colombia. The effect of using each sprinkler irrigation type and using fertigation is measured against the use of the traditional surface irrigation method. In this evaluation fertigation can be used with any sprinkler type. The different strengths, weaknesses, opportunities and threats were identified according to the baseline assessment, questionnaires and the limiting factors analysis developed in this feasibility study with support of local expert knowledge.

	Effect on strengths and opportunities (3=High, 2=Medium, 1=Low, N=Not apply)					*Effect on weaknesses and threats (3=High, 2=Medium, 1=Low, N=Not apply)*			
Strengths (Advantages)	*PVC plug with outlets*	*Mini-Wobbler*	*Impact sprinkler*	*Fertigation*	***Weaknesses (Disadvantages)***	*PVC plug with outlets*	*Mini-Wobbler*	*Impact sprinkler*	*Fertigation*
Increases crop yield	1	2	2	3	Requires initial investment cost	2	3	3	3
Increases labor productivity	2	2	2	2	Requires skilled labor	2	3	3	3
Decreases disease risk	2	2	2	2	Requires additional O&M budget	1	2	2	3
Increases water application uniformity	1	3	3	N	Requires a level of water quality	1	2	2	3
Field water savings	3	3	3	N	Waste of materials	2	2	2	2
Minimizes fertilizer loss	2	3	3	3	Risk of clogging of emitters	1	2	2	1
Reduces soil evaporation	2	2	2	2	Water pumping costs	2	2	2	2
Opportunities (Incentives)	*PVC plug with outlets*	*Mini-Wobbler*	*Impact sprinkler*	*Fertigation*	***Threats (Constraints)***	*PVC plug with outlets*	*Mini-Wobbler*	*Impact sprinkler*	*Fertigation*
Contributes to economic growth by increasing yields	3	3	3	3	Under-development of market supply	1	3	3	3
Possibility of introducing water fee per volume of water used per farm	2	3	3	3	Theft of materials and equipment	N	3	3	3
More time available for other activities	2	2	2	2	Cultural constraints on adequate water management	3	3	3	3
Less pollution of groundwater and surface water downstream	2	2	2	3	Inaccurate communication between water management institutions	3	3	3	3
Reduction of water fee for implementing technology	3	3	3	3	Lack of willingness of farmers to improve productivity	N	N	N	N

Increased experience of using solar energy for water pumping	3	3	3	3	Risk of water not being available for downstream users due to reduction of drainage flows	3	3	3	3
Strengthen rules for limiting expansion of oil palm areas in order to obtain sustainable water savings	1	3	3	3	Risk of not achieving sustainable water savings as oil palm areas are increased	2	2	2	2
Irrigation water supply priority in times of water scarcity	3	3	3	3	Risk of oil palm area being replaced by banana area.	1	1	1	1

Table 4. SWOT analysis for adopting different drip irrigation types, fertigation and alternative surface irrigation (through windows) in oil palm farms in the Sevilla basin, Colombia. The effect of using each drip irrigation type, using fertigation and using alternative surface irrigation (through windows) is measured against the use of the traditional surface irrigation method. In this evaluation fertigation can be used with any drip irrigation type. The different strengths, weaknesses, opportunities and threats were identified according to the baseline assessment, questionnaires and the limiting factors analysis developed in this feasibility study with support of local expert knowledge.

	Effect on strengths and opportunities (3=High, 2=Medium, 1=Low, N=Not apply)					*Effect on weaknesses and threats (3=High, 2=Medium, 1=Low, N=Not apply)*			
Strengths (Advantages)	*Self-compensating dripper*	*Surface irrigation through windows*	*Hose (no dripper)*	*Fertigation*	***Weaknesses (Disadvantages)***	*Self-compensating dripper*	*Surface irrigation through windows*	*Hose (no dripper)*	*Fertigation*
Increases crop yield	1	2	2	3	Requires initial investment cost	2	3	3	3
Increases labor productivity	2	2	2	2	Requires skilled labor	2	3	3	3
Decreases disease risk	2	2	2	2	Requires additional O&M budget	1	2	2	3
Increases water application uniformity	1	3	3	N	Requires a level of water quality	1	2	2	3
Field water savings	3	2	2	N	Waste of materials	2	2	2	2
Minimizes fertilizer loss	2	3	3	3	Risk of clogging of emitters	1	2	2	1
Reduces soil evaporation	2	2	2	2	Water pumping costs	2	2	2	2
Opportunities (Incentives)	*Self-compensating dripper*	*Surface irrigation through windows*	*Hose (no dripper)*	*Fertigation*	***Threats (Constraints)***	*Self-compensating dripper*	*Surface irrigation through windows*	*Hose (no dripper)*	*Fertigation*
Contributes to economic growth by increasing yields	2	2	2	2	Under-development of market supply	1	3	3	3
Possibility of introducing water fee per volume of water used per farm	2	3	3	3	Theft of materials and equipment	1	3	3	3
More time available for other activities	2	2	2	2	Cultural constraints on adequate water management	3	3	3	3
Less pollution of groundwater and surface water downstream	2	2	2	3	Inaccurate communication between water management institutions	3	3	3	3

Reduction of water fee for implementing technology	3	3	3	3	Lack of willingness of farmers to improve productivity	N	N	N	N
Increased experience of using solar energy for water pumping	3	3	3	3	Risk of water not being available for downstream users due to reduction of drainage flows	3	3	3	3
Strengthen rules for limiting expansion of oil palm areas in order to obtain sustainable water savings	1	3	3	3	Risk of not achieving sustainable water savings as oil palm areas are increased	2	2	2	2
Irrigation water supply priority in times of water scarcity	3	3	3	3	Risk of oil palm area being replaced by banana area.	1	1	1	1

Table 5. SWOT analysis for adopting different water harvesting techniques in oil palm farms in the Sevilla basin, Colombia. The effect of using water harvesting techniques is measured against the lack of use of these technics. The different strengths, weaknesses, opportunities and threats were identified according to the baseline assessment, questionnaires and limiting factors analysis developed in this feasibility study with support of local expert knowledge.

	Effect on strengths and opportunities (3=High, 2=Medium, 1=Low, N=Not apply)					*Effect on weaknesses and threats (3=High, 2=Medium, 1=Low, N=Not apply)*			
Strengths (Advantages)	*Mulching*	*Planting pits*	*Vegetative strips*	*Rooftop and reservoir*	***Weaknesses (Disadvantages)***	*Mulching*	*Planting pits*	*Vegetative strips*	*Rooftop and reservoir*
Increases crop yield	2	2	2	2	Requires initial investment cost	1	1	1	2
Increases labor productivity	2	2	2	2	Requires skilled labor	2	2	2	3
Decreases disease risk	2	2	2	2	Requires additional O&M budget	2	2	2	3
Increases water application uniformity	N	N	N	N	Requires a level of water quality	N	N	N	N
Field water savings	N	N	N	N	Waste of materials	1	2	1	2
Minimizes fertilizer loss	3	3	3	N	Risk of clogging of emitters	N	N	N	N
Reduces soil evaporation	3	2	3	N	Water pumping costs	N	N	N	N
Opportunities (Incentives)	*Mulching*	*Planting pits*	*Vegetative strips*	*Rooftop and reservoir*	***Threats (Constraints)***	*Mulching*	*Planting pits*	*Vegetative strips*	*Rooftop and reservoir*
Contributes to economic growth by increasing yields	2	2	2	2	Under-development of market supply	1	1	1	2
Possibility of introducing water fee per volume of water used per farm	N	N	N	N	Theft of materials and equipment	1	1	1	2
More time available for other activities	2	2	2	3	Cultural constraints on adequate water management	3	3	3	3
Less pollution of groundwater and surface water downstream	2	2	2	3	Inaccurate communication between water management institutions	N	N	N	N
Reduction of water fee for implementing technology	N	N	N	N	Lack of willingness of farmers to improve productivity	2	2	2	2
Increased experience of using	N	N	N	N	Risk of water not being available for downstream users	1	1	1	1

solar energy for water pumping					due to reduction of drainage flows				
Strengthen rules for limiting expansion of oil palm areas in order to obtain sustainable water savings	1	1	1	1	Risk of not achieving sustainable water savings as oil palm areas are increased	1	1	1	1
Irrigation water supply priority in times of water scarcity	N	N	N	N	Risk of oil palm area being replaced by banana area.	1	1	1	1

5 Selection of the appropriate irrigation technology and water harvesting techniques

Based on the SWOT analysis done in section 4, the most favorable irrigation technology to be adopted by the oil palm farms in the Sevilla basin is sprinkler irrigation, 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 that these water harvesting techniques are already a common practice in the region; thus, no implementation limitations are foreseen.

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 farms 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.

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. Capacity can be built, and support can be provided in determining monthly crop water requirements to optimize the irrigation system design, but also for planning the irrigation schedule. Crop water requirements can be determined with remote sensing techniques for all the oil palm farms in the Sevilla basin. Also, the soil moisture can be measured in selected farms with in-situ sensor technology to support decisions on when and how much to irrigate.

Based on this SWOT analysis and other previous work, an approach will be developed to address the limiting factors and an action plan will be prepared to set up a pilot project which will include the mentioned remote sensing and in-situ measurements to support the irrigation decision processes.

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