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# "Medium and Short-Term Scenarios of Regional Berry Production in Huiramba, Michoacán, Mexico."

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**SUMMARY**
In Huiramba, Michoacán, Mexico, the technical, social, and environmental factors affecting the production of forest fruits, mainly strawberries for export, are being analyzed. The study of the area regarding water footprint has resulted in collateral impacts, primarily of an environmental nature, leading to discontent among the population due to adverse phenomena resulting from these impacts. Through a methodology that involves calculating implicit indicators of fresh fruit production for export, the collateral production analysis is conducted, determining the water footprint, production potential, and environmental impact generated in medium and short-term scenarios. The results indicate that in three scenarios, the amount of resources allocated for production exceeds the availability of water for future generations. As a result, there is a need for the development of public policies that respect the human right to water and a healthy environment, prioritizing it over the overproduction of fresh export products and the overexploitation of the aquifers that supply water to the inhabitants, wildlife, subsistence agriculture, and agricultural production for export.

## I. INTRODUCTION

Since 2017, the municipality of Huiramba has implemented the methodology presented as a proposal to assess short-term scenarios amid the booming berry production, with strawberries being the predominant fruit, accounting for over 90% of production. However, the specific plant varieties remain unknown as they are provided on loan through productive collaboration agreements with three companies: Biotecnología, Driscoll´s Anieberries, and Grupo Bimbo. The strawberry and berry varieties cultivated in Huiramba are known for their phenological development characteristics and water-intensive production cycles. (AgroDer. 2012)

The main objective of the study in the productive area is to determine the water coefficient through the water footprint generated by the large volumes of strawberries produced per unit of surface area, considering the production potential to evaluate environmental impact and potential scenarios at 2, 6, and 10 years in Huiramba, Michoacán.

It is important to note that the production has experienced exponential growth without significant improvements in cultivation practices, and irrigation conditions associated with phenological phases and adverse hydro-climatic factors have not been analyzed from a risk perspective concerning water demand for production and its scarcity for other essential uses. (Fabian, et al. 2021)

The methodology used to determine the water coefficient, production potential, and environmental impact is based on specific formulas. In this study, the Water Coefficient is calculated concerning the production and exportation of an average of 60 tons of strawberries per hectare. It considers the productive water footprint based on the stomatal conductance of leaves, population density per km², current production potential, rainfall over the territorial extension, and a water potential coefficient to estimate the variation in precipitated rainfall (Reyes, 2019) and the water required for high levels of berry productivity. (Al-Karaki, et al. 2012)

Likewise, the production potential is determined using a second formula that takes into account the level of education and productive age by gender of the population (INEGI 2017). This becomes an eligibility criterion set by the contracting companies, along with the aforementioned water footprint (Hoekstra 2009). It allows the estimation of the unit cost of strawberry harvesting based on yields and the annual production period divided into 12 months. (Kijne, et al. 2003)

The third formula analyzes the environmental impact, measured by water consumption or expenditure, through the water coefficient and production potential calculated with socio-environmental factors aimed at preserving water quality as it is the primary resource used. (García, et al. 2013)

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Once the percentage of the environmental impact is analyzed, secondary factors such as public health problems caused by the direct and indirect use of agrochemicals, which are abundant in the berry production process to control pests and diseases (Terán, et al. 2021), are identified. These issues are considered chronic and acute toxicological problems. Additionally, the use of auxiliary products in crop nutrition is expected to increase as the population grows (registered until 2020 with 9,015 inhabitants, 48.2% male and 51.8% female), leading to more frequent and complex challenges. Furthermore, scenarios at 5 and 10 years anticipate a decrease in water quality and quantity (Hoekstra, 2009) due to the same demographic growth per inhabitant density per hectare. It is essential to consider that the technology of macro-tunnels and acreage per hectare generates an average of 4 tons/3.1m³ of plastic waste per decade.

In the medium term, the proposed scenarios foresee significant public health, food, and water security issues and air, surface, and groundwater pollution. These problems will have substantial economic, social, and environmental consequences, necessitating the formulation of public policies to address the resulting deterioration (Mekonnen et al. 2010). As the benefiting companies may not assume these costs, the economic viability of the current business model may eventually lead to the municipality's abandonment of personnel and facilities.

**Context of the Productive Zone**

The municipality of Huiramba is located in the center of the State of Michoacán, Mexico, at coordinates 19º33' north latitude and 101º26' west longitude, with an elevation of 2,100 meters above sea level. It covers an area of 79.23 square kilometers.

The predominant soil types in the region are Chernozen and Podzolic soils. According to the data provided to the Secretariat of Agriculture, Livestock, Rural Development, Fisheries, and Food, the land use in the area comprises 3500 hectares for agricultural purposes, 2190 hectares for livestock, 1844 hectares for forestry, and 558 hectares designated for other uses. This information is faithfully extracted from the Huiramba Municipal Development Plan for the period 2015-2018, published in the Official Gazette of the State of Michoacán on January 15, 2016.

**Fig.1 Location of the municipality of Huiramba.**

## II. METHODOLOGY

The study was conducted by generating scenarios at 2, 6, and 10 years and determining a Water Coefficient (QH), Production Potential (PP), and a third formula resulting from the interaction of the aforementioned formulas to assess the percentage of Environmental Impact (IA) and the issues present in the municipality of Huiramba, specifically related to berry production. These issues are expected to worsen over time, particularly in the key scenarios of 2, 6, and 10 years, leading to the depletion of water resources in terms of quantity and quality (Terán, et al. 2021). Additionally, chronic and acute public health problems may arise due to direct and indirect exposure of individuals to agrochemicals, and there could be a loss of soil productivity, affecting local food security. (Gleick, 2004)

The formulas proposed for calculating the Production Potential, Water Coefficient, and Environmental Impact for the scenarios at 2, 6, and 10 years are as follows:

**Water Coefficient (QH)**

$$QH = \frac{(HH+dp)-(FF*AF*DP)}{(PP*Qinf*AV)-(CPH*.80)} *100$$

QH = Water Coefficient
HH = Water Footprint
PP = Production Potential
Qinf = Infiltration Coefficient
CPH = Water Potential Coefficient (surface availability level 0.8)
FF = Minimum Water Requirements for Production according to Strawberry Phenology
AF = Free Water for Strawberry Productivity, considering high yields per hectare
DP = Population Density/ha
dp = Per Capita Water Availability for the Population
AV = Virtual Water

This formula considers rainwater as the primary and only source of liquid water supply for living beings, considering it as a renewable resource. However, it's essential to note that although it is renewable, it is limited. We depend on rainwater to utilize it properly, following the principles of the water cycle, to harvest it and maintain it with the highest possible quality to ensure its abundance and availability. This concept is what we refer to as water footprint. Additionally, we must consider the effects of technologies like anti-hail devices, commonly known to the population as hail cannons. (Pulido, et al. 2020)

This is why the production potential is considered a factor in the water coefficient. It brings together elements that align with proposed technical and scientific theories and methodologies, taking into account fundamental aspects such as the number of plants per hectare (plantation density), plant varieties, adaptability level, and unit weight of harvested species. Unfortunately, demographic elements such as productive age and educational background of the population involved in these types of crops, mainly established by multinational corporations in the production region, are disregarded.


**Fig. 2 "Photographic capture by Marcial Reyes Cázarez of the distribution center located on the Huiramba - Cuanajo road."**

The Production Potential (PP) formulation takes into account the educational level, as lower educational attainment can result in reduced resource utilization and effectiveness in mastering the production process. Additionally, costs, yields, production periods, and the annual distribution of gross output are evaluated.

**Production Potential**

$$PP = \frac{NE+ET+CU+Ren+PTP}{12} * 100$$

PP = Production Potential
NE = Educational Level
ET = Production Territorial Extension
CU = Unit Cost per kg
Ren = Yield per hectare
PTP = Productive Temporal Period
12 = Months of the Productive Year

The use of appropriate technology in the production of berries in the municipality of Huiramba has been enhanced, leading to the opening of the market for mulching, irrigation systems, and macro tunnels. The companies involved are expanding to other nearby municipalities such as Tiripetio, Acuitzio, and Umécuaro, where the conditions are favorable in terms of the terms and variables used in the formulas proposed in this research. (Fig. 3.)

**Fig. 3"Photographic capture by Marcial Reyes Cázarez of thecropontheboundaries of Huiramba and Pátzcuaro."**

In the proposed calculation of Production Potential, it is essential to emphasize that the contractual terms of agricultural property rental, plant loan, and the agreement for exclusive production with owners and holders of ejidos, communities, and small properties are taken into account. In these arrangements, the production system is established, and the supervision and control of production by technicians assigned by the companies are of vital importance. This situation primarily leads to a decrease in Production Potential and contributes to an increase in the Environmental Impact index through negative interactions and resource depletion. (SEMARNAT 2015)

Environmental Impact

$$IA= \frac{PP*\$m^3\Delta ext}{QH-m^3\Delta trat} *100$$

IA = Environmental Impact
QH = Water Coefficient
$\Delta$ext = Extraction Cost per $m^3$ [19]
PP = Production Potential
$\Delta$trat = Cost of Wastewater Treatment per $m^3$

The feasibility and profit margin of companies are also enhanced by the availability of resources, where low-educated human resources allow for optimized salaries based on production rates, granting access to previously analyzed natural resources, which are under pressure due to production and serve as indicators of environmental performance. This promises to generate emerging employment opportunities but at the cost of high resource depletion. It is important to mention that the water resource, crucial for high productivity, must be extracted at a low cost and ensure abundant availability. However, over time, due to the use of agrochemicals and unsustainable practices, the quality and quantity of the water resource diminish. (SEMARNAT 2012)

It should be noted that the data possessed by companies for the preparation of this study is highly confidential, exclusive in terms of processes, productivity, transparency, and legal operation in the municipality.

The proposed methodology applied to berry production in Huiramba, Michoacán, Mexico, can be applied to any type of crop in any geographical location where it intends to be implemented, as it is based on the principles of sustainability and low-impact agricultural practices, developed through models designed at the Technological Institute of Pátzcuaro as part of the author's research line.

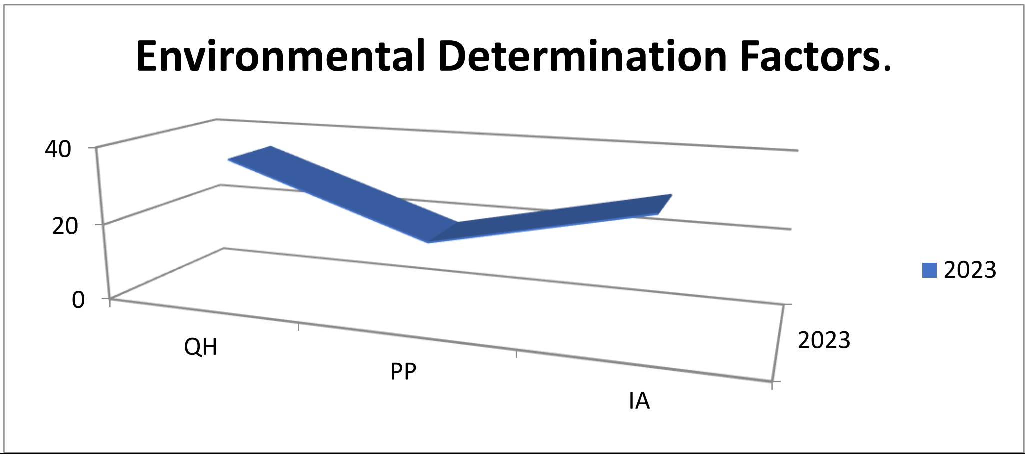
## III. RESULTS

The constitutive use of water per capita and virtual water for berry production in the municipality of Huiramba, Michoacán, is calculated according to the costs presented by the Mexican Institute of Water Technology. Currently, the cost per water investment is higher than local purchasing costs.

What is not considered in the municipality is the pollution of wastewater from this process, in liquid and gaseous form, which leads to short-term local environmental problems. The high use of organochlorine, organophosphorus, and herbicides (glyphosate and paraquat) agrochemicals, which are not quantified or valued under a productivity and residual rate, places the responsibility of guaranteeing access to drinking water and a healthy environment on the municipality, without knowledge of the secondary effects of these activities, as there is no monitoring system for them.

If we quantify according to the treatment rates proposed by the IMTA for these specific treatments of water contaminated by agrochemicals, the annual budget allocated for this purpose would not be sufficient.

By implementing the Water Coefficient (QH), Production Potential (PP), and Environmental Impact (IA) methodology determined for the year 2023, as a result of the analysis conducted on the established companies in the region, it shows that it is optimal to guarantee their investments at a null or very low level of risk. The per capita availability of water per inhabitant, without considering Virtual Water required for crops, registers an average yield of 60 tons per cycle per hectare, implementing drip irrigation, mulching, and macro tunnels. (Fig. 5)




| | 2023 |
|---|---|
| QH | 39.15 |
| PP | 20.37 |
| IA | 43.11 |

**Fig. 4 Graph of Results of Environmental Performance Factors**

In the results previously presented in Figure 4 of the determination factors, we can observe that the water coefficient is 39.15%, representing 100% water availability for berry production in this municipality. Previously, water was abundant and maintained similar levels of rainfall, but now both variables have decreased by up to 30%. Additionally, the population density per hectare is very low, leading to a higher per capita water availability, due to migration factors where over half of the population does not reside in the municipality.

Regarding the production potential (20.37), it indicates the level of resource utilization for strawberry production, neglecting training and efficient resource use. It's essential to consider that the educational level, based on data from INEGI, is an average of 5.5 years of education, corresponding to a lack of knowledge about the resources they possess. Within the agreements made for crop loan and land rental, there is an imminent lack of knowledge about legal processes and the responsibilities they entail.

Currently, after 9 years of formal operation of the companies, the productive agricultural process of berries in the Municipality of Huiramba used to occur within a 6-month cycle, but nowadays, practices and conditions allow it to extend up to 9 months, resulting in increased water consumption and decreased soil productivity. This implies an increase in natural and chemical nutrient inputs to maintain productivity per hectare of red berries.

Determining the environmental impact and both factors that derive from it, such as productivity and water cost, allows us to contextualize scenarios calculated for the next ten years, applying the same factors and elements proposed for the years 2029 and 2033. This enables us to generate a development context, as presented in the following table.

**Table 1 - Results of Environmental Performance Factor Scenarios**

| Year | QH | PP | IA |
|---|---|---|---|
| 2025 | 41.25 | 22.14 | 47.28 |
| 2029 | 49.58 | 26.18 | 60.55 |
| 2033 | 72.14 | 23.12 | 74.18 |

In the projection of the scenario for the year 2029, we can observe that the water coefficient increases, which is a result of the exponential growth of the cultivated area and a decrease in rainfall indices in the region. This decrease is due to the fact that the population density remains within stable parameters of demographic growth. Additionally, the Production Potential increases because by 2029, the productive population will have a better understanding of production processes. However, there is a possibility of a lack of replacement personnel due to accelerated labor turnover.

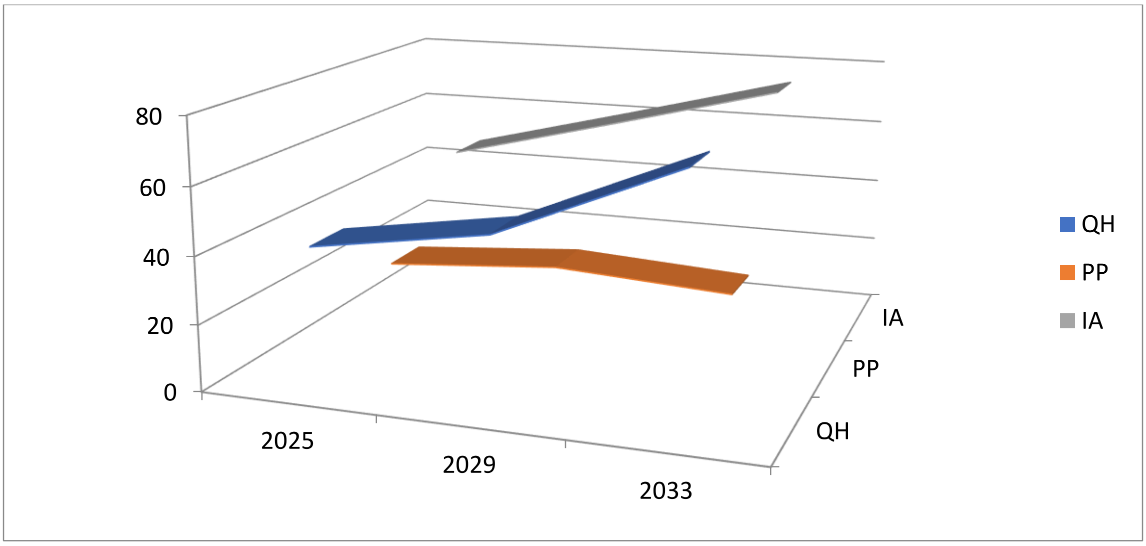



Fig. 5 Graph of Results of Scenarios and Interaction of Environmental Performance Factors.

As we can observe in the previous graph, the water coefficient (QH) and the production potential show an inversely proportional trend. As the water resource depletes, the production decreases, while the environmental impact constantly increases, considering the economic costs of water extraction and treatment at different levels, water consumption, and productivity well below the analyzed extraction levels. Additionally, the generation of special waste in the medium and long term, along with their management plans and proper disposal, must not be overlooked.

As a result of several production cycles, the availability of water resources for the primary needs of the population lacks the required physicochemical properties for human consumption and requires additional specific treatments (Kijne, et al., 2003).

## IV. CONCLUSIONS.

The municipality of Huiramba faces severe environmental problems and water stress due to population density and the expansion of high-water-demand crops such as berries for export production (SAGARPA, 2006). This study clearly shows that the expansion of berry production results in a high water consumption with specific physicochemical requirements for export crops (SEMARNAT, 2012).

One of the adversities faced by the municipalities within the Lake Pátzcuaro Basin is the accelerated loss of forested areas, replaced by monoculture avocado orchards (Gómez Tagle, 2018). The forested areas, mainly composed of temperate forest with pine-oak forests, are not considered for the production of berries, as they are established on agricultural land with high availability of irrigation water. However, at some point, the surface area may no longer meet the required demand for production.

Since 1994, berry production has diversified, and its volume has grown equally or even more than avocado production, making it the second significant export production in the state of Michoacán (SAGARPA, 2017). The production area has expanded to neighboring municipalities with high water reserves and availability, seeking conditions similar to those in Huiramba regarding community development level.

The municipality of Huiramba, through springs and rivers, not only provides water to its territory but also contributes to the hydrological basin of Lake Pátzcuaro, supplying the Cointzio and Umécuaro reservoirs.

The pressures on the management of these three water bodies aggravate problems related to their water storage levels and quality (Dorward, 2013).

The population's dissatisfaction is increasing due to the majority of people working in the cultivation area coming from other communities, as a result of the multiple diseases prevalent among the local population, with kidney diseases being the most common.

Finally, it is crucial to mention that once the estimated environmental impact reaches 100%, the availability of the resource will be limited, leading to water shortages in the municipality and an increase in health deterioration, reduced quality of life, and survival of living beings, including the inhabitants of the municipality (SEMARNAT, 2015).

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