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Increasing the Productivity of the Value Chain Using Precision Agriculture

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Abstract

This research proposes a new alternative to improve the agricultural sector, since the expected demand is currently not being met and there is a considerable variation in the prices of some mass consumption products, which affects the consumer due to the very high prices of some products such as lemon, quinoa, onion, etc. This proposal is based on precision agriculture, which has meteorological stations that will monitor and control the care of the products and the proper use of fertilizers, pesticides and water. Furthermore, through precision agriculture it will be possible to establish direct contact between the farmer and the sellers, as well as to see in real time the evolution of said agricultural products and the expected production, since there will be web and mobile applications to control the high prices that are generated at certain times of the year due to shortages of some products, which can have a cost increase of up to 700% of their normal price. Precision agriculture will also take into account the measured use of certain inputs (water, pesticides, fertilizers), which will lead to significant cost reductions for the benefit of farmers.

Keywords
Precision agriculture, weather stations, productivity increase, value chain, technical and economic feasibility.

1. Introduction
This study will evaluate the technical and economic feasibility of precision agriculture, which consists of weather stations and web and mobile applications, resulting in increased agricultural production in a planted area. Furthermore, with the control and monitoring of products, we can affirm that their components will be more nutritious. Peru is currently experiencing a period of technological growth, which contributes to cost reductions when precision agriculture is employed and to the optimization of the use of technology. Therefore, a study is being conducted in the agroindustry that uses precision agriculture to increase productivity in the value chain of any agricultural product. To meet annual crop demand, precision agriculture will be necessary to optimize production per square meter of cultivated land, since if the product does not meet the estimated demand, the prices of various products will increase considerably. A clear example is the price of lemons in Peru, as every year there are seasons in which their price reaches seven times its normal price.

The overall objective of the research was: "To intervene in the environmental monitoring of the Colpamayo and San Mateo micro-basins using automatic meteorological and hydrometric stations equipped with GSM/GPRS technology

as part of water resource management, Chota." (Environmental monitoring of the Colpamayo and San Mateo micro-basins using automatic meteorological and hydrological stations, 2022)

Weather stations have been used by meteorological services and private companies as a mechanism for determining weather conditions and for keeping historical records of data for a region. (Fernando Ureña Elizondo, Vol. 11, No. 1, 2021)

The agricultural market study showed that the harvested production was not as expected, with constant losses due to weather factors, fertilizers, water, etc. The proposed technology seeks to achieve higher harvest yields per cultivated area.

We also describe the technology we use for precision agriculture, which consists of installing meteorological stations (land and environmental) on agricultural land, which will be monitored and supervised using web applications and apps.

This type of agriculture will reduce the costs of sowing, growing, and harvesting agricultural products. Farmers will realize that, with precision agriculture, they will achieve higher crop yields, better food quality, and lower financial costs. These savings are justified because sensors will be used to inform us about which areas of agricultural land actually need irrigation, fertilizers, pesticides, etc.

The social impact on the region will be significant, as this project will generate economic savings in the quinoa planting, cultivation, and harvesting processes. In addition, it will boost sales to both domestic and international markets. It will improve the socioeconomic status of farmers and, therefore, of the region. Furthermore, environmental pollution will be reduced by reducing pesticide use. The web and mobile application will also integrate the farming population into a more globalized world. Since they currently do not constantly use technological equipment such as cell phones or mobile applications, this means that when precision agriculture is implemented, we as a company must train residents in the technology needed to ensure they can consistently use these web and mobile applications.

1.1 Objectives

This research aims to design meteorological stations to measure and control the resources used in agricultural products. To this end, the following objectives were defined:

- Determine the technical and economic feasibility of implementing precision agriculture engineering in a crop area.
- Design, develop, and integrate precision agriculture engineering modules.

2. Literature Review

Previous studies, such as those conducted by the National Meteorological Service (SMN), indicate that these stations provide highly reliable data, which is very helpful for precision agriculture. The development of precision agriculture will bring about a global change in the way harvesting is carried out and its forecasting in terms of projected demand. First, it will provide a semi-automated way of carrying out work. Therefore, in the field of agriculture, there will be a major advance, and the traditional method, which consists of farmers' experience with the seasons and months of the year, will no longer be used. However, as is well known, the planet is currently exposed to variations in the start and end dates of the seasons, which is generating a greater variation and margin of error in farmers' time capture, generating harvest losses and leaving farmers with minimal profit. The change of seasons and seasons is varying a lot, affecting the harvests and reducing the final product of an expected demand that was had and thus it is not possible to cover what was requested by the applicants (herkasova, S., M. M. Skansi, N. Garay, 2025)

Likewise, there is a lot of interest from institutions in Peru such as MIDAGRI that is interested in precision agriculture, since lately in our territory the climate has been changing a lot and the seasons have become considerably out of phase, therefore the way farmers cultivate is being affected because they, by instinct or their own experience, that is why when they have orders for an agricultural product, they do not satisfy the expected demand and that causes prices to rise and the consumer is economically affected. That is why MIDAGRI is interested in obtaining meteorological stations, web and mobile applications, in order to have a smaller margin of loss in the products and imbalances do not occur.

Currently, educational institutions such as the Agrarian University are conducting pilot projects in precision agriculture. (Agraria.pe) The Quinua SmartApp will allow real-time monitoring of organic quinoa fields from a cell

phone. This platform, which is in the prototype phase, will make it possible to detect pests, nutrient deficiencies, or low temperatures using modern precision agriculture technologies.

Developed by a team of agricultural, mechatronic, systems, physics, telematics, and computer science experts from the University of Lima and the National Agrarian University of La Molina, it will help improve quinoa productivity and achieve more efficient resource management. "It's a technological platform that has various components. For example, through the web or mobile application, farmers can monitor the behavior of temperature, weather, humidity, or any pests that may be present in the growing area. It also functions as a marketplace where they can promote their product and conduct future commercial transactions."

Precision agriculture is an agricultural practice that uses advanced technologies, such as remote sensing, smart irrigation systems, and nanotechnology, to optimize natural resource management and increase agricultural productivity. This discipline emerged as a response to contemporary agricultural challenges, such as increasing food demand, resource scarcity, and environmental impacts. By collecting, analyzing, and applying large volumes of data in real time, precision agriculture enables farmers to make informed decisions and quickly adapt to changing environmental conditions. While precision agriculture offers innovative solutions, its full potential has yet to be realized. Continued research and development of new technologies is needed, as well as improving accessibility and adoption by farmers. Zain, M., Ma, H., Chaudhary, S., Nuruzaman, M., Azeem, I., Mehmood, F., Aiwang D. & Sun, C. (2023). Nanotechnology in precision agriculture: Advancing towards sustainable crop production. Plant Physiol

3. Methods

In precision agriculture, the growth of the crops to be harvested in a specific area is monitored and controlled. The precision agriculture we are working with relies on weather stations that measure different parameters using the following sensors:

- Atmospheric pressure
- Air and soil humidity at different distances (15 cm, 30 cm, 45 cm)
- Temperature
- Solar radiation
- Wind direction and speed
- UV radiation

All these parameters will be sent to a mobile app created for the research. This will give farmers a better view of their crops. They will also be able to view all the data in real time and determine when it is most convenient to harvest and then ship them to consumers. With these parameters, we will obtain better crops, reduce production costs, and reduce crop losses. In this way, we will be able to standardize and avoid price increases due to shortages of various crops. We will be able to predict an approximate amount of crops and thus avoid creating a price imbalance. (Figure 1).

Figure 1. Operation of a meteorological station in the crop field

Variables have a nomenclature and a unit of measurement that we must take into account, which are the following in Table 1.

Table 1. Nomenclature and units

VARIABLE	NOMENCLATURE	UNIT
Hourly air temperature	T(h)	°C
Hourly relative humidity	HR(h)	%
Hourly accumulated precipitation	P(h)	mm/h
Accumulated precipitation in 24 hours	PT(h)	mm/24h
Hourly water level	NIV(H)	m

4. Data collection

To consider the functioning of meteorological stations, we will focus on quinoa on this occasion, as it is a widely used product in Peru (Table 2).

Therefore, we have the regional annual quinoa production figures compiled by MINAGRI. These figures can be understood by other measurement factors such as the planted or harvested area and the yield provided by the areas worked by quinoa producers. Therefore, MINAGRI also presents the table of quinoa production area and yield for the period 2018 to 2023, which describes the yield of the cultivated land relative to the final harvested product.

Table 2. Quinoa production, harvested area and yield, 2018-2023

Years	Production (T)	Harvested Area (ha)	Yield (T/ha)
2018	105,666	69,303	1,525
2019	79,269	64,223	1,234
2020	78,657	61,721	1,274
2021	86,011	65,787	1,320
2022	89,414	65,280	1,380
2023	89,414	66,584	1,458

Note: Adapted from Quinoa Production, Area, and Yield, 2018-2023, by the Ministry of Agriculture and Irrigation (MINAGRI, 2023).

Demand Projection

For demand projections, the evolution of national demand corresponding to the population over this period will be used as a database. The important data to be extracted are the equation used by the National Institute of Statistics (INEI) for population projections, its growth rate, and the distribution of the population with respect to quinoa demand.

Over the last 20 years, population growth has adopted a downward trend, with the rate of population growth changing every few years. According to the INEI, this change occurs every five years. The most recent growth rate, from 2018 to 2023, was 1.1% annual growth, while the following period is projected to grow at 1%. This can be seen in the population growth graph.

Population projection equation:

$$\Delta P = P^*(1+T^*\Delta t)$$

Where:

ΔP: Grown population or future population

P: Base or starting population

T: Population growth rate

Δt: Time elapsed in years to be evaluated relative to the base year

5. Results and Discussion

5.1 Numerical Results

The precision agriculture analysis will show various changes that we must take into account and observe in great detail if we want to realize the significant changes that we are going to have, for that we are going to take into account 2 fundamental aspects, the first will be that we will be able to cover the required demand on an annual basis and this will generate that the price of the market value of quinoa, the product that we are taking as a sample, does not change so drastically, the second significant change will be the extra income generated by the sale of quinoa since in addition to being able to cover the local need, it will also be able to export and this would generate a considerable income for the economy in our country.

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To achieve the expected results, we must project several parameters: annual demand to be covered, income from decreased annual shrinkage (Table 3).

Table 3. International market demand for quinoa, its capital income, and its yield, 2018-2024.

years	National Demand (T)	International Demand (T)	Apparent Domestic Demand (T)	National production (T)
2018	51,001	36,400	87,401	105,666
2019	51,562	41,800	93,362	79,269
2020	52,129	50,400	102,529	78,657
2021	52,703	49,600	102,303	86,011
2022	53,283	48,900	102,183	89,414
2023	53,869	40,500	94,369	97,057
2024	54,407	42,100	96,507	86,834

It can be observed that normally in the vast majority of years the demand for quinoa is not satisfied, this means that due to scarcity prices are going to rise, it is also known that the price of quinoa in millions of dollars per ton is $2.34, this means that farmers are not receiving a considerable amount of money, therefore we have the following table where we can observe that the decrease in quinoa is considerable (Table 4).

Table 4. Demand and production

Years	Total Demand(T)	National Production(T)	National Production without loss(T)	Extra yield without loss ($/T)
2018	87,401	105,666	132,083	63,493
2019	93,362	79,269	99,086	47,631
2020	102,529	78,657	98,321	47,263
2021	102,303	86,011	107,514	51,682
2022	102,183	89,414	111,768	53,727
2023	94,369	97,057	121,321	58,320
2024	96,507	86,834	108,543	52,177

In the following table we can see how much it would support precision agriculture, not only meeting the expectations that are projected annually, but also in the economic part, it would be generating considerable money, since this technology reduces waste by 20%. Which generates a very large benefit for the population, since it will meet the national expectation and then it can be exported. (Table 5)

Table 5. Projection Without Precision Agriculture

years	projection without precision agriculture(t)	proyection with precision agriculture(t)	price (millions $ / t)	extra money that would be earned by having precision agriculture
2026	93,867	117,334	2.34	54,912
2027	96,972	121,215	2.34	56,729
2028	100,077	125,096	2.34	58,545
2029	103,181	128,977	2.34	60,361
2030	106,286	132,857	2.34	62,177
2031	109,391	136,738	2.34	63,994

The raw material requirement was calculated in relation to the demand for the final product, "Meteorological Stations." Each station requires various sensors, which will be explained in detail later.

Our final product consists of two types of stations (environmental and terrestrial), each weighing approximately 5 kg. It also includes an app that allows farmers to monitor the planting, cultivation, and harvesting of quinoa. The use of this device will increase the quality and production of the product.

Below is a list of materials found in a weather station (both ambient and ground-based) (Table 6):

Table 6. List of materials found in a weather station

N°	Materials	Amount
1	Raspberry Pi	2
2	Arduino	2
3	Battery	2
4	Solar Panel	2
5	Charge Controller	1
6	Rain Gauge	1
7	Temperature Sensor	1
8	Humidity Sensor	1
9	Anemometer	1
10	UV Radiation Sensor	1
11	Aluminum Rod (3 m)	1

Note: Adapted from the List of Materials Found in a Weather Station (Management, 2019)

The total price is 550 dollars; therefore we can conclude that it is not an excessive cost, which will be used for an area of 300 square meters

5.2 Graphical Results

We can see that if precision agriculture had been implemented years ago, the required demand in Peru would have been met without a price increase. Therefore, it is very important to implement precision agriculture to achieve considerable savings in lost production and also to ensure that prices in the country of origin do not fluctuate (Figure 2).

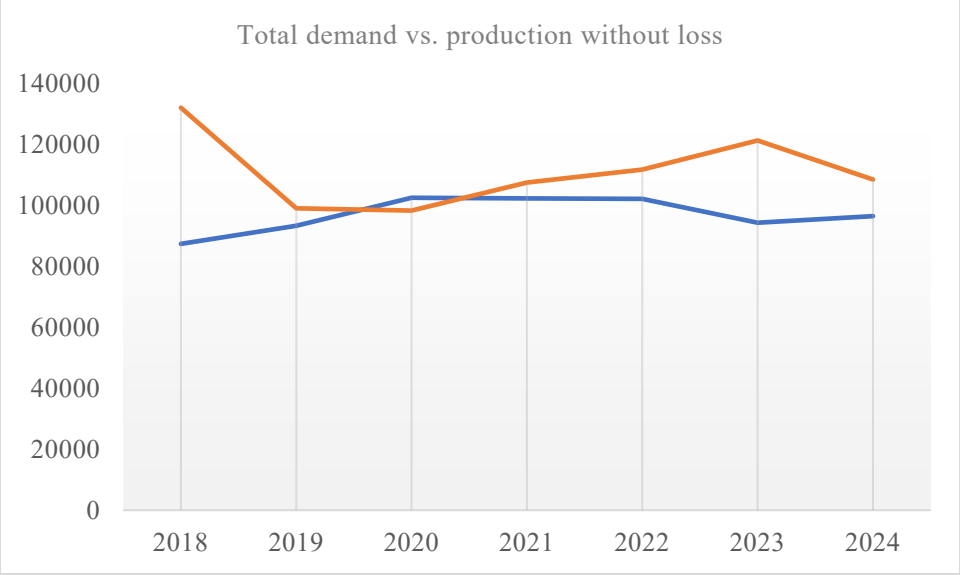

Figure 2. Demand vs production (Orange: production without loss, Blue: required demand for quinoa)

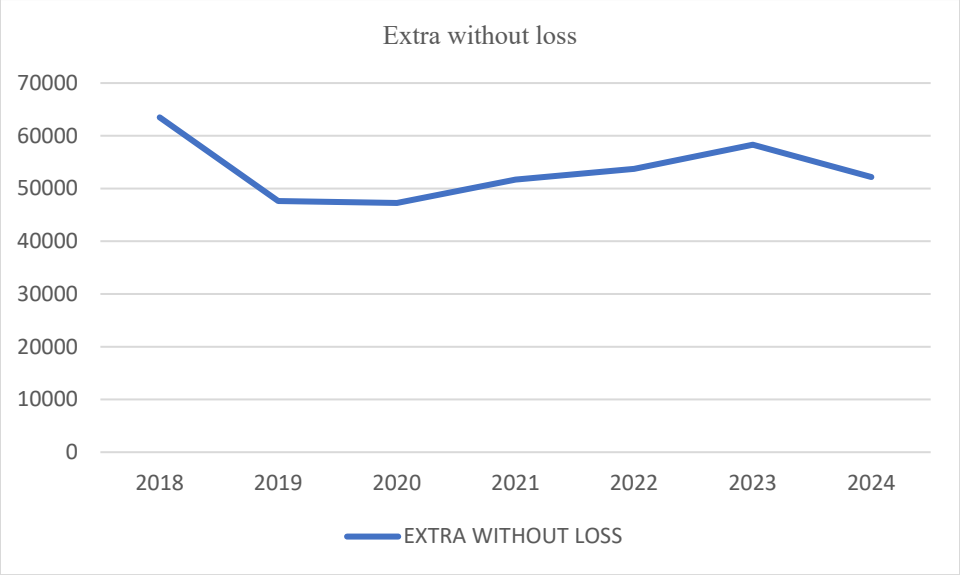

Figure 3. Annual loss of money by farmers

The graph (Figure 3) shows the annual loss of money by farmers due to losses caused by the misuse of inputs (water, pesticides, insecticides). This not only affects local consumers but also the foreign market. For this reason, establishing meteorological stations would be an optimal option to address this deficit in the agricultural sector.

Below we can see the graph of the projected extra money that would be earned if precision agriculture were used, which shows us that using this new technology will not only bring about social changes because the farmer will learn new agricultural techniques, but will also bring about considerable economic changes (Figure 4).

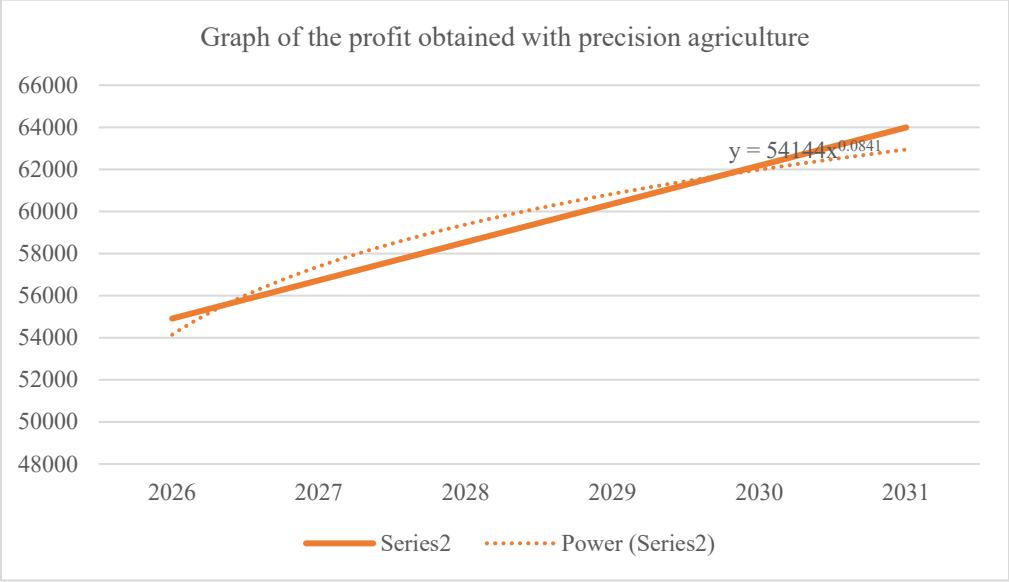

Figure 4. Profit obtained with precision agriculture

5.3 Proposed Improvements

The project "Quinua Smartapp, a prototype of a real-time, intelligent rural platform to increase productivity in the organic quinoa (Chenopodium quinoa wild) value chain," developed by the National Agrarian University La Molina, the peasant community of San Lorenzo de Huancayo, and the University of Lima in coordination with the National Agrarian Innovation Program (PNIA) and with funding from the World Bank and the Inter-American Development Bank.

5.4 Validation

Once the prototype is complete, data collection from the sensors will be tested using the Arduino Mega and transmitted to the Raspberry Pi 3 board. This data will then be transmitted to the cloud (the Internet) using the Zigbee board.
Tests will be conducted at the Agrarian University and then in the field (at the quinoa planting site).
Once the data is monitored in the cloud (the Internet), it will be evaluated, and if the data does not meet our expectations, some stage of the design will be modified to optimize its use according to the needs of agricultural specialists. The end result is an efficient environmental monitoring station.

6. Conclusions

The project will promote the use of precision agriculture technology, which consists of weather stations. These technologies generate higher yields in agricultural products, as a larger harvest can be obtained from the same planted area, maximizing production and minimizing potential losses or waste. Agricultural costs are also reduced, as monitoring is constant and precise throughout the planting, cultivation, and harvesting processes, obtaining accurate data on the amount of water, fertilizers, insecticides, etc.

The project also produces positive social results, as it will generate awareness of technological tools among farmers and provide them with direct contact with sellers. Farmers will also be able to receive training in marketing to attract better buyers and better offers that benefit them.

In addition to the good yields obtained through precision agriculture, farmers must receive training to be able to export products that exceed the domestic market.

Using the web application or app will have several benefits not only for farmers but also for buyers. These applications allow for viewing crops and the characteristics of different farms, making it easier for buyers to choose the food product they want to purchase.

Acknowledgments

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