Determination of some Key Performance Indicators for some strategic crops within South Bekaa Irrigation scheme in Lebanon

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Abstract. The study was carried out during the 2021 growing year from April through October, in plots cropped with wheat, potato, onion, silage corn and peach, within South Bekaa Irrigation Scheme (SBIS) in Lebanon, within the frame of SUPROMED (Sustainable Production in water limited environments of Mediterranean agro-ecosystem) project (2019-2022). Data was used to calculate (i) annual irrigation water supply per unit irrigated area ($m^3\ ha^{-1}$), (ii) yield per unit irrigation supply (kg m^{-3}), (iii) gross margin per unit water required by crops, GM-W_r (€ m^{-3}), (iv) gross margin per unit irrigation supply, GM-I_s (€ m^{-3}), (v) units of nitrogen per unit irrigated area, UN-I_a (kg of pure units of nitrogen ha^{-1}) and (vi) units of nitrogen per unit water supply, UN-I_s (kg of pure units of nitrogen m^{-3}). An agro-economic questionnaire was prepared to gather data from farmers, and compare it with that of a reference material approved by SUPROMED.

Results showed that corn ranked first with the highest annual irrigation water supply per unit of irrigated area (8463 $m^3\ ha^{-1}$), compared to wheat (2430 $m^3\ ha^{-1}$), while peach and potato have been shown to have the highest yield per unit of irrigation supply (11.96 and 11.12 kg m^{-3}, respectively), compared to wheat (5.42 kg m^{-3}) and corn (6.98 kg m^{-3}). On the other hand, the highest gross margin per unit of water evapo-transpired by the crop, and per unit of irrigation supply was found on peach (3.987 € m^{-3} and 3.588 € m^{-3}, respectively), making of peach the most profitable crop in the study area. Concerning nitrogen, results showed that the highest amount of pure nitrogen units per unit of cultivated land, was found on potato (345.25 kg UN ha^{-1}), and the lowest on wheat (128.25 kg UN ha^{-1}) and onion (277.37 kg UN ha^{-1}), making of potato the most efficient crop in using nitrogen. Moreover, the highest amount of pure nitrogen units per unit of irrigation water was found on potato (0.065642 kg UN m^{-3}), while the lowest on corn (0.045227 kg UN m^{-3}). Results also showed that plots monitored by SUPROMED had the lowest seasonal irrigation water supply per unit of irrigated area ($m^3\ ha^{-1}$), and the highest yield per unit of irrigation supply (kg m^{-3}), which contributed to increased gross margin per unit of water used by crops (GM-W_r) and unit of irrigation supply (GM-I_s). However, units of nitrogen per unit of irrigated area (UN-I_a) and per unit of water supply (UN-I_s) were found to be higher in the farmer's monitored plots, compared to plots monitored by SUPROMED.

1 Introduction

Not only is agriculture the main source of livelihood, but it is also a major support of the national income since it provides a broad range of employment as well as the basic raw material for production. One of the key-factors in sustainable agriculture is the efficient use of resources including water, nutrients, and other inputs. Nowadays, increasing agricultural water productivity has gained much global attention due to the decline in fresh water supplies, the increase in frequent droughts caused by climate change, and the surge in demand for food crops. (*FAO, 2017*)

However, in order to set a management plan, one must study the behavior of the plants by examining different measures. That's why SUPROMED, "Sustainable Production in water limited environments of Mediterranean agro-ecosystem", a research and innovative project founded by PRIMA, studies different key-performance indicators related to water, energy and fertilizers in several strategic crops, in order to place an effective management scheme that eventually enhances the economic as well as the environmental sustainability of Mediterranean farming systems *(Supromed.eu, 2021)*.

This study mainly focused on calculating a set of key-performance indicators (KPI) for some crops, within South Bekaa Irrigation Scheme (SBIS). Information needed for the calculation of the KPIs was gathered from a group of leader and average farmers, who were identified in SBIS during the 2020 growing year within the scope of SUPROMED, and for which the different plots were selected in 100 km^2 large polygon (5 km wide x 20 km long), covering the 21,500 ha SBIS irrigated area. The main objectives were to (i) determine Key Performance Indicators (KPIs) on water, nitrogen and Gross Margin, of five strategic crops typical of the cropping pattern in South Bekaa Irrigation Scheme and (ii) come up with recommendations and guidelines on the farming systems of the five crops, to increase crop and water productivity, and optimize Gross Margin. The specific objectives were to (i) analyze the impact at farm level with the implementation of SUPROMED at Lebanon's demo site and (ii) analyze the socio-economic and environmental impacts at national level, and upscale it to the Mediterranean scale, considering different policy frameworks.

2 Material and Methods

2.1 Plot selection

The demo site is located in the South Bekaa Valley in Lebanon, and within South Bekaa Irrigation Scheme (SBIS), the one command irrigation area is 21,500 ha. Due to financial constraints, only a pilot area of 2000 ha has a pressurized irrigation network in the meantime, with the rest of the scheme still dependent on ground artesian wells for irrigation. Clayey soils containing relatively low organic matter are attributed to the study area. Soil erosion is very uncommon in this region, since field slope is less than 2% and totally available water within the topsoil reaches 190 mm. A Mediterranean semi-arid climate governs the area of research, thus expressed by a hot and dry weather between the months of May and September, and a cold, wet weather for the rest of the year. The standard seasonal rainfall reaches 850 mm, of which 95% is documented between October and May, and only 5% falling between April and May, thus indicating the likelihood of a drought at this time of the year. Plots grown with wheat, potato, onion, corn and peach have been selected during the 2020 and 2021 growing years, within a polygon of 100 km^2 in area (5 km wide x 20 km long), which was identified for the scope of SUPROMED project (Figure 1).

2.2 Description of the agro-economic questionnaire

The gathered data from farmers served in building up a set of KPIs for each crop, and compare the results with that of a reference material approved by SUPROMED, to help the farmers upgrade their systems, hence increasing their revenues while decreasing their total costs. An agro-economic questionnaire was prepared to serve as a research instrument, providing relatively cheap, quick and efficient information. This survey was carried out two groups of farmers, Leader Farmers (LF) and Average Farmers (AF), according to a classification applied by SUPROMED, for which the results would be extendable to a third group of farmers, known as 'Associated Farmers' (Table 1). Table 2 gives the different growth stages of the five surveyed crops.

The questionnaire includes 5 different parts:

Part A: Bio-physical information. This part focuses on general information related to the farmer, crop variety, plot area and land tenure.

Part B: Agronomic information. In this section, the main focus is on the sowing and harvesting dates, soil nature, type of tillage practices and crop rotation.

Part C: Water management practices. This segment is directly related to the irrigation habits carried out by the cultivators. It includes the type of irrigation, source of water, irrigation intervals and durations, and most importantly the quantity of water involved per season.

Part D: Fertilization. The focus is on the type of fertilizers applied as well as the quantity, the time of application, the method adopted, the microelement mostly needed by the plant.

Part E: Costs and Revenues. This part aims on assembling the costs implied during the cultivation process. Plus collecting the revenues obtained from the farm gate price of the products, taking into consideration the overall yield of the land.

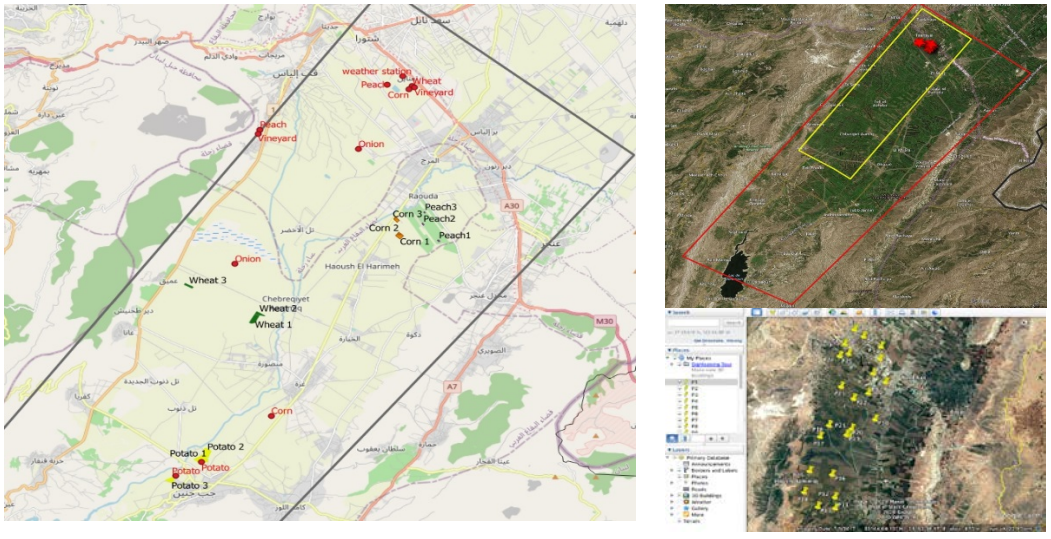

Figure 1. Plot selection within South Bekaa Irrigation Scheme

Table 1. List of farmers' selected

	Installation date	Farmer's name	Category	Location	x (East)	y (North)	z (m)
iMetos weather station	04/05/21			Taanayel	35°52'12.20"	33°47'47.18"	879
Wheat	04/05/21	Domain Tanayel	Supromed	Tanayel	35° 52' 26.4"	33° 47' 32.8"	879
	04/05/21	Elie Hawli	Average	Kab Elias	35° 54' 46.4"	33° 48' 39.8"	878
Potato	05/05/21	Mohammad Charanek	Leader	Jeb Janine	35°46'33.51"	33°38'0.24"	861
	05/05/21	Michel Estephan	Average	Jeb Janine	35°47'12.21"	33°38'20.51"	865
Peach	04/05/21	Domain Tanayel	Supromed	Tanayel	35° 51' 49.6"	33° 47' 35.3"	883
	15/05/21	Khaled Haydar	Leader	Kab Elias - Bmhrein	35° 48' 39.4"	33° 46' 29"	900
Onion	15/05/21	Elie Abou Rjeili	Leader	Hawch Ammiq	35° 48' 2.3"	33° 43' 11.8"	873
	05/06/21	Nasser Hatoum	average	Kab Elias	35° 51' 06.2"	33° 46' 00.4"	875
Vineyard	22/05/21	Joe Touma	Leader	Kab Elias - Bmhrein	35° 48' 36.2"	33° 46' 22.3"	913
	12/06/21	Domain Tanayel	Supromed	Tanayel	35° 52' 29.6"	33° 47' 31.6"	873
Corn	26/06/21	Salam Charanek	Leader	Ghazzeh	35° 48' 56.4"	33° 39' 28.5"	870
	17/07/21	Domain Tanayel	Supromed	Tanayel	35° 52' 21.2"	33° 47'27.8"	873

Table 2. Crop calendar showing the different growth stages of the five surveyed crops

	2020	2021								
	December	January	February	March	April	May	June	July	August	September
Wheat	Sowing	Emergence	Listing	Tillering	Bolting/Heading	Grain filling	Harvest			
Potato				Sowing	Late veg growth	Stolonization	Tuber bulking	Harvest		
Onion			Sowing	Vegetative growth	Bulb initiation	Bulb thickening	Bulb ripening	Bulb mature	Harvest	
Silage corn						Sowing	Vegetative growth	Anthesis/Silking	Grain filling	Harvest
Peach					1st leaf/Budding	Blooming	Fruit set/fruit bulking	Fruit bulking	Harvest	Post-harvest
Vineyard				Weaping	Bud break	Leaf growth	Flowering/Fruit set	Veraison	Grape ripening	Harvest

2.3 Calculation method of KPIs

Data gathered from the different interviews with leader and average farmers in this study were used to calculate the six KPIs. A comparison will be made between leader and average farmer and Supromed-monitored plot. To recall that for potato and onion there were no plots monitored by the Supromed team, and the comparison will be made in this case between leader and average farmer. As mentioned earlier in this report, the energy-related KPIs have not been determined for the current season, given the fluctuations in daily prices of diesel and fuel and other energy producers. As a result, the calculated KPIs are:

1. Annual irrigation water supply per unit irrigated area (in m^3/ha);
2. Yield per unit irrigation supply (in kg/m^3);
3. Gross margin per unit water required by crops (GM-Wr) (in €/m^3);
4. Gross margin per unit irrigation supply (GM-Is) (in €/m^3);
5. Units of nitrogen per unit irrigated area (UN-IA) (in Kg of pure units of nitrogen/ha);
6. Units of nitrogen per unit water supply (UN-Is) (in Kg of pure units of nitrogen/m^3).

Glossary:

a) **KP1:** VT-IS expresses irrigation volume, or irrigation module, in m3/ha;

b) **KP2:** Y-IS expresses the agronomic productivity of irrigation water (designated as APW). It is the ratio of the yield of the crop (Y, in kg/ha) to the volume of gross irrigation water applied (IS, in m^3):

c) Water productivity (WP) relates the yield of the crop (Y_a) (kg/ha) to the actual evapotranspiration (ET_a) (m^3) *(Çetin & Kara, 2019)*:

$$WP = \frac{Y_a}{ET_a}$$

WP is KPI-related indicator.

d) Gross margin of production (GM) calculated as

$$GM = V_p - C_t$$

Where Vp is the total value of the commodity, including subsidies (€/ha) and Ct is the total costs (variable plus fixed costs).

a) **KP3:** GM-Wr. It expresses GM per unit of water used by the crop, or evapotranspiration (Net irrigation + effective rain) Unit of measurement: €/m3 (López-Mata et al., 2019)

$$\frac{GM}{Wr} = \frac{GM}{(I_N + Pe)}$$

e) **KP4:** GM-Is. It expresses GM per unit water irrigation supply. Unit of measurement: €/m^3.

$$\frac{GM}{Gross\ irrigation\ water} = \frac{GM}{Is}$$

f) **KP5:** UN-IA. It denotes Unit Nitrogen used per irrigated area. Unit of measurement: kg UN/ha.

$$\frac{N}{Irrigated\ area} = \frac{UN}{IA}$$

g) **KP6:** UN-IS. It represents Unit Nitrogen per irrigation water supply. Unit of measurement: kg UN/m^3.

$$\frac{N}{Gross\ irrigation\ water} = \frac{UN}{IS}$$

h) Agronomic productivity of Nitrogen (APN) relates the yield of the crop (kg/ha) to the Nitrogen units applied (NU) (Fang and Su, 2019):

$$APN = \frac{Y_a}{NU}$$

Unit of measurement: (kg yield/ha) / (kg NU/ha). APN is KPI-related indicator.

3 Results and Discussion

3.1 KPI-based results

The KPIs of each crop were calculated in LF's and AF's plots, and in the plot monitored by the SUPROMED research team. Figure 2 shows that the silage corn ranked highest among all the monitored crops (VT-IS of 8463 m^3/ha), compared to wheat with the lowest irrigation module (2430 m^3/ha). This is because corn is a water consumer, and requires higher amounts of water, especially during the grain filling period, which extends over sixty days after silking. Figure 2 also shows that peach and potato have the highest IWUE (Y-IS), 11.96 and 11.123 kg/m^3, respectively, compared to the lowest IWUE on wheat (5.42 kg/m^3) and corn (6.98 kg/m^3). This may be due to the fact that the peach tree receives water by the means of a drip irrigation system that utilizes water efficiently and produces a high fresh fruit yield. Figure 3 demonstrates that for GM-Wr, peach had the highest outcome, followed by onion, silage corn, potato and finally wheat with a very low input. These results are very similar to those of GM-Is (Figure 3). For both KPIs, the highest GM per m^3 of water used by the plant (GM-Wr) and per m^3 of irrigation (GM-IS) was found on peach (3.987 and 3.588 €/m^3, respectively). As for nitrogen related KPIs, the results showed that UN-IA (Figure 4) was the highest for potato (345.25 UN/ha), followed by silage corn, peach, onion and finally wheat. Moreover, for UN-IS (Figure 4), which took into consideration the ratio of pure nitrogen applied to gross irrigation volume, the highest amount of pure nitrogen units per unit of irrigation water was found on potato (0.065642 kg UN/m^3, or 6.5642 g/m^3) while the lowest was found on corn (0.045227 kg UN/m^3 or 4.5227 g/m^3).

Decreasing the volume of water deployed in irrigation and increasing yield contributed to increased agronomic productivity of irrigation water (Y-IS) and water productivity (WP). On the other hand, gross margin (GM) was found to improve with decreasing total costs, being the sum of variable and fixed costs. Among all costs, fertilization were ranked the first in terms of amounts per hectare, followed by the costs of energy (fuel), and seeds. Concerning nitrogen fertilization, our results showed that both the agricultural productivity of Nitrogen (APN) and Unit Nitrogen per irrigation water supply (UN-IS), have been improved with reduced amount of applied water for irrigation. The improvement of any of the studied KPI will undoubtedly lead to water savings, reduced production costs and decreased pressures on the environment. Concerning agricultural productivity of nitrogen (APN), our results demonstrated that onion was the most efficient crop in using nitrogen. Based on the results we recommend an optimal water management of potato, wheat, onion, corn and peach in order to increase the economic return of these crops under the prevailing climatic and soil conditions of the South Bekaa.

4 Summary

A Farmer Field Assessment (FFA), consisting in an agro-economic survey with a sample of 10 leader and average farmers, as per the classification proposed by SUPROMED, was conducted during the 2021 growing year in south Bekaa Irrigation Scheme, to gather relevant information on the farmer and farming systems, which will help understanding the current farmer's practices and suggest a set of Good Agricultural Practices for demonstration in selected pilot plots within SUPROMED project. The gathered data from farmers served in building up a set of KPIs for each crop, and compare the results with that of a reference material approved by SUPROMED, to help the farmers upgrade their systems, hence increasing their revenues while decreasing their total costs, with respect to (i) crop rotation, (ii) fertilization and (iii) irrigation management.

Based on the above, it was concluded within the frame of this study that:

- Corn has the highest irrigation module (VT-IS): 8463 m^3/ha compared to wheat with the lowest irrigation module (2430 m^3/ha);
- Peach and potato have the highest IWUE (Y-IS): 11.96 and 11.123 kg/m^3, respectively, compared to the lowest IWUE on wheat (5.42 kg/m^3) and corn (6.98 kg/m^3);
- The highest GM per m^3 of water used by the plant (GM-Wr) and per m^3 of irrigation (GM-Is) was found on peach: 3.987 and 3.588 €/m^3, respectively;
- The highest amount of pure nitrogen units per unit of cultivated land (UN-IA) was found on potato (345.25 kg UN/ha), while the lowest on wheat (128.25 kg UN/ha) and onion (277.37 kg UN/ha);
- The highest amount of pure nitrogen units per unit of irrigation water was found on potato (0.065642 kg UN/m^3, or 6.5642 g/m^3) while the lowest was found on corn (0.045227 kg UN/m^3 or 4.5227 g/m^3).

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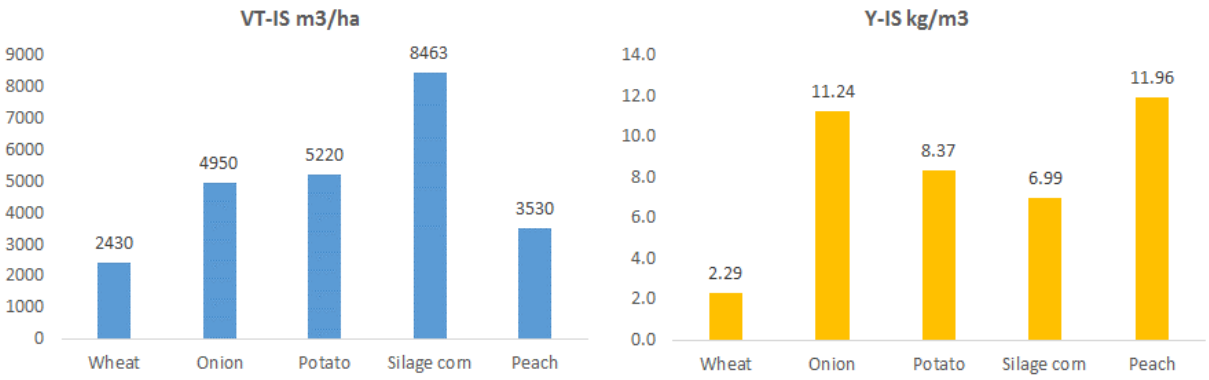

Figure 2: Charts summarizing the results obtained for VT-IS and Y-IS on the measured crops

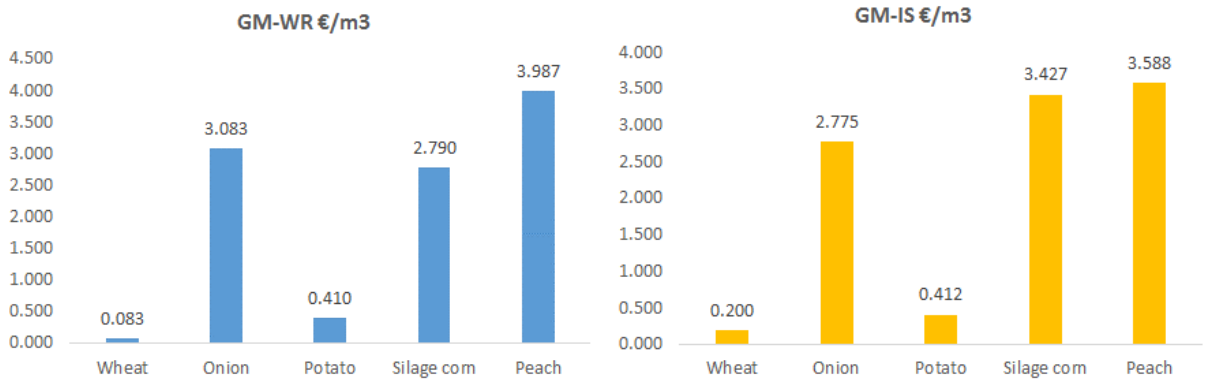

Figure 3: Charts summarizing the results obtained for GM-WR and GM-IS on the measured crops

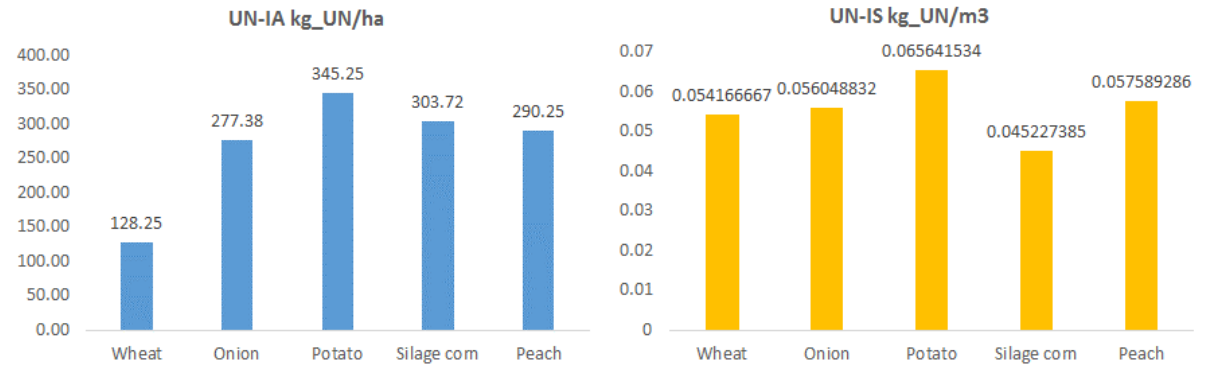

Figure 4: Charts summarizing the results obtained for UN-IA and UN-IS on the measured crops

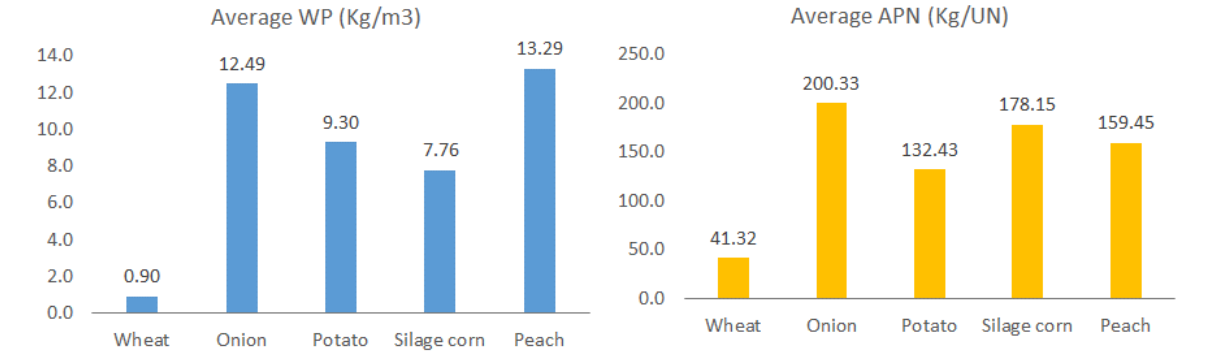

Figure 5: Chart summarizing the results obtained with WP and APN on the different crops