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MANAGEMENT OF CROPS INTENSIFICATION IN EGYPT TO OVERCOME WATER SCARCITY

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ABSTRACT
Irrigation water management has become very important task to be implemented in Egypt due to the prevailing conditions of water scarcity. Thus, technologies are required to increase water and land productivity. The objective of this paper was to suggest management package to overcome water scarcity conditions in Egypt. It included precise land leveling and cultivation on raised beds to save 25%, as well as changing crops sequence from two crops per year to three crops per year and implementing different intercropping systems. We suggested to cultivate short season clover, soybean or bean between winter and summer crops and to implement intercropping in one season and in two seasons. The results indicated that cultivating short season clover can be implemented because its water requirements will be available as a result implemented precise land leveling and cultivation on raised beds. The results also indicated that either intercropping in one season or two seasons can be implemented to increase land and water productivity. In addition, short season clover can be also cultivated between summer and winter seasons in some of these intercropping systems. Thus, our proposed management of crops intensification can be the solution for food gaps problems under water scarcity situation in Egypt.

Key words: Precise land leveling, cultivation on raised beds, cultivation of three crops per year, and intercropping.

1. INTRODUCTION
Egypt is characterized by limited water and soil resources, in addition to high population rate. Irrigation water management has become very important task to be implemented in Egypt due to the prevailing conditions of water scarcity. In addition, low application efficiency of surface irrigation, which is the prevailing irrigation system [1].This situation creates challenges for agricultural scientists to manage water more efficiently, taking into consideration soil and water resources conservation. Thus, innovations are required to increase water and land productivity under water scarcity conditions. Furthermore, these innovations need to easy to be implemented by farmers to increase their adoption to these new technologies.

Precise land leveling is one of these technologies that can be used to reduce the applied water to surface irrigation without any losses in crops productivity. Previous research indicated that precise land leveling increased water use efficiency for several crops in Egypt. Furthermore, it can save 5% of the applied irrigation water [2 and 3]. Moreover, cultivation on raised beds can save 20% of the applied irrigation water. It was also reported that cultivation on raised

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beds increased productivity by 15%, as a result of increase in radiation used efficiency as crops are more exposed to solar radiation, increase nitrogen use efficiency and increase water used efficiency [4, 5 and 6].Thus, 25% of the applied water to surface irrigation can be saved and used to cultivate a third crop in between the cultivated summer and winter crops. This innovative crop sequence, for example, can be early winter, winter then summer crop or winter, early summer then late summer crop. The major reason behind using this system is to sustain and improve soil fertility and increase farmers' income [7].

Furthermore, implementing intercropping, where one crop share its life cycle or part of it with another crop [8] can be used as a mean to save on the applied irrigation water, improve soil fertility and increase farmers' income [9]. The advantages of intercropping are: it increase unit land productivity (harvest two types of crops from the same area), increase water productivity (use less water to irrigate two crops) and increase farmers income (reduce risks from crop failure) [10].

Several papers have been published in Egypt to highlight the roll of intercropping systems on soil and water sustainability. Two intercropping systems on wheat were implemented and reported in Egypt. The first system was intercropping wheat with tomato by cultivating tomato in the 1st of October on the raised bed with 100% planting density. After 45 days, wheat was cultivated in two rows at each side of the raised beds, with 75% planting density and its productivity will be 90%, compared to wheat sole planting. Under this system, wheat plants use the applied amounts of water and fertilizer to tomatoes [11]. Another successful intercropping system was reported, which is relay intercropping cotton on wheat, where wheat was cultivated in November and cotton is cultivated in March and share two month of its life cycle with wheat (wheat was harvested in April). The benefits of this system are to increase wheat cultivated area by the area assigned to be cultivated by cotton and the last two irrigations for wheat were used by cotton plants. Under this system, the farmer obtained two yields: the same cotton yield as if it was planted solely and 80% of wheat yield, compared to sole wheat planting [12].

Regarding to maize, several intercropping systems were implemented. Intercropping soybean with maize can increase land and water productivity. In this case, soybean is cultivated on the top of the raised beds and maize is cultivated on the edges of the raised beds after 21 days. No irrigation water will apply to maize because it will take its water requirements from the applied water to soybean [13]. Another effective intercropping system is cowpea intercropped with maize, which proved to increase maize yield and reduced associated weeds. No additional water will be applied for cowpea under this system. Maize productivity was increase by 10% under this system and no reduction in cowpea productivity occurred [14]. Relay intercropping potato on maize is another successful system, where maize was cultivated in 2nd week of June with 100% planting density on one side of the raised beds and potato was cultivated on the other side in August with 100% planting density. Thus, this system allows early cultivation for potato, where maize plants provide warmth to potato plants and that allowed early harvest when its price is high. Under this system, potato will share its first two irrigations with maize. Maize was harvested in end of August. Then, potato continued its life cycle and harvested in November [15]. Lastly, maize can be intercropped with tomato, where maize was cultivated three weeks after tomato, each plant species on one side of the raised bed. Maize planting density was 70% of the recommended, whereas tomato planting density was 100%. The benefits of using this system is that maize plants perform as shed over tomato plants and protect its fruits from damage by sun rays. This system saved 100% of the applied water for maize as it use the applied water to tomato plants [16].

Intercropping onion with sugar beet system is also beneficial. Sugar beet was planted in October on both sides of the raised beds with 100% planting density and onion was planted in November in two rows on the beds, with 33% of recommended planting density. Onion gets its water requirements and fertilizer from the applied water and fertilizers to sugar beet [17].

In Egypt, there is a large gap between production and consumption of faba bean. This gap can be overcome by intercropping it with other crops, such as tomato and sugar beet. Tomato was cultivated in the beginning of September, with 100% planting density and faba been was cultivated in the beginning of November with 50% of recommended

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planting density [18]. Faba bean intercropped with sugar beet increase land and water productivity because no extra irrigation water or fertilizer is applied to faba bean. Sugar beet was cultivated to maintain 100% of its recommended planting density and faba bean was cultivated by 12.5% of its recommended planting density. As a result, the farmer can obtain 100 and 25% of sugar beet and faba bean, respectively [19].

Thus, cultivating three crops per year and/or intercropping integrates the advantages of well-developed eco-agricultural techniques [20], which need more evaluation of its potential contribution to agricultural sustainability. Thus, the objective of this paper was to suggest management package include precise land leveling, cultivation on raised beds, changing crops sequence from two crops per year to three crops per year and implementing different intercropping systems to overcome water scarcity conditions in Egypt.

2. MATERIALS AND METHODS

2.1. The selected sites

El-Gharbia governorate (Lat. 30° 47' 27" N, Long. 30° 59' 53" and Elev. 22 m above sea level) is located in the Nile Delta and was selected to represent clay soil. The clay soils in Egypt are the most fertile soils in the Nile Delta and Valley. However, poor management of these soils reduced its organic matter content due to continual growing of exhaustive crops like cereals. Surface irrigation is prevailing with 60% application efficiency. The cultivated crops are grown on either basins or on rows, where two crop sequence practice (a winter crop followed by a summer crop) is prevailing for either field crops or vegetables.

2.2. Calculation of crops water requirements

The required irrigation water need to be applied to the studied crops under surface irrigation (Table 1) was estimated using BISm model [21]. Normals weather data (1985-2014) was used in these calculations. The model requires planting and harvest dates as input. The model calculates crop coefficient (kc) and accounts for water depletion from root zone. Planting and harvest dates for the studied crops were obtained from bulletins published by Agricultural Research Center.

Table 1. Sowing and harvest dates for winter and summer field and vegetable crops planted in the Nile Delta of Egypt.

Winter crops			Summer crops		
Crop	**Sowing date**	**Harvest date**	**Crop**	**Sowing date**	**Harvest date**
Wheat	15-Nov	18-Apr	Maize	15-May	1-Sep
Clover (short)	15-Sep	5-Nov	Maize (late)	15-Jul	5-Nov
Clover (2 cuts)	15-Sep	28-Feb	Maize (forage)	15-Aug	15-Oct
Clover (full)	15-Sep	15-Mar	Rice	15-May	10-Sep
Sugar beet	15-Sep	12-Mar	Soybean	15-Apr	13-Jul
Sugar beet	15-Oct	12-Apr	Sunflower	15-Apr	17-Jul
Sugar beet	15-Nov	12-May	Pepper	1-Apr	8-Aug
Flax	15-Nov	13-Apr	Eggplant	1-Apr	8-Aug
Flax	1-Nov	30-Mar	Beans	15-Mar	15-May
Faba bean	25-Oct	25-Mar	Cotton	15-Mar	1-Sep
Garlic	15-Sep	15-Feb	Potato	1-Aug	28-Nov
Garlic	1-Sep	2-Feb	Tomato	1-May	1-Sep
Tomato	1-Oct	1-Mar			
Tomato	15-Sep	1-Mar			

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Furthermore, water requirements for the above crops were calculated under saving of 25% of the applied water to surface irrigation.

2.3. Prevailing and suggested crops structure

Prevailing crop sequence per year involves cultivation of wheat followed by maize or rice, which are exhausting the soil. Furthermore, sugar beet is usually followed by rice or maize. Similarly, flax usually followed by maize, which has bad effect on the soil. With respect to suggested crops sequence, we suggested that the management package should be used to provide irrigation water to allow cultivation of the third crop. Furthermore, when suggesting crop sequence, cereal crops should be followed by legume crops and crops with shallow roots should be followed by crops with deep roots to maintain soil fertility (Table 2). The water required to irrigate these crop sequences were calculated using BISm model.

Table 2. Prevailing and suggested crops sequences.

Prevailing crops sequence	Suggested crops sequence
Wheat then maize	Clover (short season), wheat then maize
Wheat then rice	Clover (short season), wheat then rice
Sugar beet then maize	Sugar beet, soybean then maize
Sugar beet then rice	Clover (short season), sugar beet then rice
Flax then maize	Flax, soybean then maize (late)
Faba been then maize	Faba bean, bean then maize (late)
Garlic then maize	Garlic, soybean then maize (late)
Clover (full season) then maize	Clover (full season), pepper then maize (forage)
	Clover (full season), eggplant then maize (forage)

Different intercropping systems were also suggested to replace monoculture and its water requirements were calculated using BISm model (Table 3).

Table 3. Prevailing crops structure and suggested intercropping systems.

Prevailing crops	Suggested intercropping system
Wheat then soybean	Wheat then soybean intercropped with maize
Wheat the rice	Wheat intercropped with tomato then rice
Sugar beet then maize	Sugar beet then potato intercropped with maize
Sugar beet then rice	Onion intercropped with sugar beet then rice
Flax then maize	Flax then soybean intercropped with maize
Faba been then maize	Faba bean intercropped with sugar beet then maize Faba bean intercropped with tomato then maize
Garlic then maize	Garlic then cowpea intercropped with maize
Clover (full season) then maize	Clover (full season) then maize intercropped with tomato
Clover (2 cuts) then cotton	Cotton relay intercropping with wheat

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3. RESULTS AND DISCUSSION

3.1. Crop sequence

The results in Table (4) indicated that when crop sequence includes clover, water saving will occur. The savings will be between 25-1517 m^3/ha. Including soybean or bean in the crop sequence will need extra irrigation water. Thus, to solve this problem we suggested to apply deficit irrigation to the middle crop, where we get the benefits of cultivating legume crop in between two exhausting crops. Soybean cultivation between sugar beet and maize will reduce the applied water to soybean to 98% of full irrigation. Cultivating soybean between flax and maize will result in reduction in the applied water to soybean to be 98% of full irrigation. Similarly, soybean cultivation between garlic and maize will reduce the applied water to soybean by 6% (Table 4).

When sugar beet is cultivated before maize or rice, it will be cultivated in 15th of October and harvested in 12th of April, then in 15th May maize or rice will be cultivated. Inclusion of soybean or short season clover in these above systems will require in the first system cultivating sugar beet in the 15th of September and harvest it in 12th of March, where soybean will be cultivated in 15th of April and harvested in July then maize will cultivated. In the second system, sugar beet will be cultivated in 15th of November to allow the cultivation of short season clover before it in 1st of September and be harvested in the 5th of November.

Table 4. Prevailing and suggested crops sequences, their water requirements and increase or decrease in total water requirements.

Prevailing crops sequence	WR (m^3/ha)	Suggested crops sequence	WR (m^3/ha)	Deviation (m^3)
Wheat then maize	16075	Clover (short season), wheat then maize	16050	+25
Wheat then rice	18800	Clover (short season), wheat then rice	18137	+662
Sugar beet then maize	18566	Sugar beet, soybean then maize (late)	18013	+553
Sugar beet then rice	21316	Clover (short season), sugar beet then rice	21391	-75
Flax then maize	16100	Flax, soybean then maize (late)	16400	-300
Faba been then maize	15933	Faba bean, bean then maize (late)	16287	-354
Garlic then maize	16400	Garlic, soybean then maize (late)	17125	-725
Clover (full season) then maize	21066	Clover (full season), pepper then maize (forage)	20513	+554
		Clover (full season), eggplant then maize (forage)	19550	+1517

WR= water requirements.

Thus, changing crop sequence from two to three crops per year can be achieved by the saving in applied irrigation water. Furthermore, using this system can face water scarcity, increase crops production and consequently increase food availability.

3.2. Intercropping in one growing season

The results in Table (5) indicated that if we implemented the management package and save 25% of the applied water, all the suggested systems will largely save on the applied irrigation water. Furthermore, the results in that table implied that saving in the applied irrigation water can be attained if we replace cultivation of two crops per year by cultivating three crops, one is a mono-cropped and two are intercropped. The saved amount will be between 2621-6609 m^3/ha. We suggested investing some of these amounts to cultivate short season clover between the summer and the winter crops if the saved amount is equal to or higher than 4038 m^3/ha, which is clover water requirements. Thus, short season clover can be cultivated before onion intercropped with sugar beet then rice. Similarly, short season clover can be planted before flax then soybean will be intercropped with maize. Short season clover can be also cultivated before garlic then cowpea

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intercropped with maize could be implemented. In the case of clover (full season) then maize intercropped with tomato and cotton relay intercropped with wheat, we cannot cultivate short season clover before the winter crops. For the first system, short season clover cannot be cultivated before full season clover as both are legumes. For the second system, wheat and cotton will stay in its cultivated area for the whole year (Table 5).

Extra irrigation water can be saved as a result of intercropping. In intercropping soybean with maize, maize will use the applied water to soybean, which is lower than the applied water to maize. In intercropping wheat with tomato, wheat will use the applied water to tomato, which is less than the applied water to wheat.

Cultivating sugar beet then potato relay intercropped with maize will use more irrigation water than cultivating sugar beet then maize because the applied irrigation water will compose of applied water to sugar beet, full applied water to maize and the applied water to potato minus the first and second irrigations, where potato will share it with the last two irrigations applied to maize. The total applied water to this system will be higher than the applied water for sugar beet then maize by 354 m^3/ha, which can be compensated from saved water from other systems. Intercropping onion or faba bean with sugar beet will not require applying more water than what is needed to fulfill sugar beet needs (Table 5).

Table 5. Prevailing crops structure, suggested intercropping systems in one growing season and their water requirements.

Prevailing crops	WR (m^3/ha)	Suggested intercropping system	WR (m^3/ha)	Saved amount (m^3/ha)
Wheat then soybean	14384	Wheat then soybean intercropped with maize	10788	+3596
Wheat the rice	18800	Wheat intercropped with tomato then rice	13487	+5312
Sugar beet then maize	18566	Sugar beet then potato intercropped with maize	18920	-354
Sugar beet then rice	21316	Onion intercropped with sugar beet then rice	15987	+5329
Flax then maize	16100	Flax then soybean intercropped with maize	10826	+5275
Faba been then maize	15933	Faba bean intercropped with sugar beet then maize	13313	+2621
		Faba bean intercropped with tomato then maize	11963	+3971
Garlic then maize	16566	Garlic then cowpea intercropped with maize	12425	+4142
Clover (full season) then maize	21066	Clover (full season) then maize intercropped with tomato	16812	+4254
Clover (2 cuts) then cotton	24366	Cotton relay intercropping with wheat	17758	+6609

3.3 Intercropping in two growing seasons

More intensive cultivation system can be implemented, where intercropping preformed in every growing season. Few examples for that system are presented in Table (6). The saved water ranged between 3971-5891m^3/ha. This large amount of saved water can be used to expand the cultivated area and reclaim new lands. Furthermore, it could be used to cultivate short season clover before winter crops and after summer crops. Thus, short season clover can be cultivated before sugar beet and after potato intercropped with maize, which will improve soil fertility. The only intercropping system that used more irrigation water is faba bean intercropped with sugar beet then potato relay intercropped with maize (Table 6).

Table (6): Prevailing crops structure, suggested intercropping systems in two growing seasons and their water requirements

Prevailing crops	WR (m^3/ha)	Suggested intercropping system	WR (m^3/ha)	Saved amount (m^3/ha)
Wheat then maize	16050	Wheat intercropped with tomato then soybean intercropped with maize	10175	5874
Sugar beet then maize	18566	Onion intercropped with sugar beet then soybean intercropped with maize	12675	5891
Faba been then maize	15933	Faba bean intercropped with sugar beet then potato intercropped with maize	18920	-2987
	15933	Faba bean intercropped with tomato then cowpea intercropped with maize	11963	3971

4. CONCLUSION

Food insecurity and water scarcity are highly correlated problems. Our results showed that crops intensification through using our suggested management package to save irrigation water and use it to cultivate three crops per year instead of two crops per year can be implemented to increase food production, maintain soil fertility and increase farmer's income. Our results also showed that intercropping can use less irrigation water and increase water productivity as two crops are using the applied water to one of them. Furthermore, intercropping can help in solving food insecurity problem through increase land productivity.

Thus, our proposed management of crops intensification can be the solution for food gaps problems under water scarcity situation in Egypt.

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