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EFFECTS OF DRIP IRRIGATION SYSTEM FOR LONG-LIFE FRUIT TREES ON DIFFERENT ECONOMIC BASES

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ABSTRACT

The important step for an agriculture project is to select from the available alternatives, based on the site conditions, the crop type, system of irrigation, system configurations, and laterals' arrangement. Based on economic selection bases, the best combination is that requires minimum initial installation cost and/or minimum total annual costs and/or minimum energy cost and/or minimum maintenance cost or gives maximum benefit/cost (B/C) ratio and/or maximum net returns and/or maximum net cultivated area. The objectives of the present study were to use the drip irrigation model TISD linked with the measures of the economic analysis to study the effect of system configurations and lateral's directions for long-life fruit trees on the selected economic bases. The study was conducted on eleven long-life fruit trees based on physical, crop, and economic conditions. The long-life fruit trees considered in the study were: apples, apricots, bananas, citrus, dates, figs, grapes, guavas, mangoes, olives, and pears. The results revealed that the drip irrigation system with configurations and laterals' direction has a very small effect on the B/C ratio, the annual net return, total annual costs, and net cultivated area. Further, the system used in the study has a very high effect on initial capital cost and annual energy cost. Moreover, the drip irrigation system configurations and laterals' direction have a considerable effect on the annual maintenance cost.

Disciplinary: Civil Engineering (Irrigation Engineering), Agricultural Sciences (Crop Science), Agricultural Water Management Engineering.

1. INTRODUCTION

Drip irrigation is the most water-efficient method of irrigation, and in developed countries is often the most cost-efficient method for high-value crops as well (Asmon and Rothe, 2006). This system of irrigation is an efficient, reliable, and economically viable water management strategy to irrigate more land areas with existing limited water resources and economic returns (Mandal et al.,

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2007). The economic assessment of the drip irrigation system in fruit crops reveals that this system can save a considerable amount of water and leads better returns regardless of the higher initial investment (Behera and Sahoo, 1998). The drip-irrigation can apply small but frequent irrigation in terms of water saving, yield, quality, and water use efficiency (Shrivastava et al., 1994; Hanson et al., 1997). The drip irrigation systems also provide the opportunity to apply an appropriate amount of nutrients and chemicals along with water, which reduces leaching losses and enhances yield, quality and water, and nutrient use efficiency (Bresler, 1977; Mohammad et al., 1999).

The effect of the sowing of the one-hectare area using a trickle irrigation system has been studied by Tiwari and Reddy (1997) on banana yield, capital cost, operating cost, and net return. The cost analysis was carried out based on yield results under different sowing geometry patterns. The analysis revealed that the net return was set to be maximally for one plant at a place of 2-m spacing. It was found that the length to width ratio of sowing has a high correlation with the initial capital cost and the total annual cost. The highest return was gained at 4-m spacing with 2 plants per location.

Cuykendall and White (1998) did the drip irrigation investment and costs in an apple orchard. The project was designed to help farmers in determining the investment, fixed and variable costs, and expected returns from drip irrigation. In the project, economic worksheets were developed to help farmers in assessing fixed and variable costs of drip irrigation. The economics of yield data were applied to replicate multi-year irrigation studies to help farmers in determining yield response from drip irrigation. Net present value (NPV) methodology was applied to estimate the discounted break-even investment results from published responses to drip irrigation, with investments in drip irrigation of $464-880 per acre for 10 acres free of trees. Within over seven years of data from the Agricultural Experiment Station in New York State, the average yield increased due to irrigation was 117 bushels per acre, resulting in a break-even investment of around $2,000 per acre.

Cetin et al. (2004) evaluate the financial investment in drip irrigation systems to help Turkish apple farmers, under the NPV criterion to determine the discounted breakeven investment results from published responses to drip irrigation systems. Farmers with typical drip irrigation systems could expect an initial investment of US$1415 per ha when the orchard blocks are 5 ha in size. The survey results indicated that NPV was US$2584 for “Granny Smith” and US$909 for “Golden Delicious”, respectively, after an initial investment of US$1415 per ha. On the other hand, the analysis indicated that, in present value terms, a farmer could spend up to US$3999 for “Granny Smith” and US$2324 for “Golden Delicious” per ha for drip irrigation systems and still break even.

Asmon and Rothe (2006) studied the economic feasibility of drip irrigation in Afghanistan. Their economic analyses were summarized in three main findings. First, drip irrigation systems make the relatively high capital costs when there is a relatively high cost associated with the use of water. Also, drip systems make sense when the water is scarce, and saving water to expand the farmer’s irrigated area is a high priority for that farmer. Finally, drip irrigation should be used exclusively when the water source is a tube well. With a deep tube-well (120m or more), drip is consistently remunerative, for all fruit types investigated; grapes, pomegranates, almonds, apricots, and apples. In sum, the overall finding of the study is that drip irrigation in Afghanistan is an important element of agricultural development policy for the medium term (5-7 years).

Mandal et al. (2007) studied guava orchard to study the effect of drip irrigation system on yield, quality, and economic return of guava production in saline soil having pH 8.18 and EC 0.95 S/m. The results of drip irrigation used for guava started bearing at 3rd year of sowing. The drip-irrigated planted guava at 6m x 6m, produced 8.31 t/ha and 15.0 t/ha, whereas at 5m x 5m, 12.0 and 21.60 t/ha after 3rd and 4th year of planting, respectively. The highest production cost (Rs. 68,764 ha-1), net profit (Rs. 82,346 ha-1) as well as B/C ratio (2.20) were higher at 5m x 5m distance.

Nassar (2009) applied micro irrigation systems (trickle and bubblers) for olive trees at Wadi EL Natrown, Egypt, with a split-plot design. The olive trees were planted in the center of an irrigated round base of 1 m diameter. The distance between the tree rows and the trees in the same row is 5 m. Concerning the hydraulic specifications and their position: 1) For the drip irrigation 4 emitters (12 l/h) for each tree placed on one lateral line PE 16 mm diameter passing through the center of the tree round base; where each emitter is 30 cm distant from the next one; 2) For the bubblers, one bubbler per each tree (100 l/h) placed in the tree round base, 25 cm distance from the tree stem moving monthly in 180º clockwise to maintain good water distribution. A comparison was made between the different systems taking into account the following points: olive trees morphology (plant height and stem diameter), shoots number for each tree, leaves a number for each tree, shadow area, and root distribution, several fruits for each tree, fruit weight, the yield for each tree, total yield per feddan (1 feddan = 4200 m^2), efficiency of the yield and both content of soil moisture and distribution of soil salt. The results obtained show the usefulness of trickle irrigation system in olive trees growing rather than the bubblers where the trees' height increased by 9.2%, stem diameter increased by 14%, shoots number per tree increased by 14%, leaves number per tree increased by 17%, shadow area increased by 13%. Also, trickle irrigation systems demonstrate the highest values of sand soil moisture content at 18, 16, and 10.5% by weight) in the soil layers (00–30), (30-60) and (60-90) cm, respectively. The olive trees' root distribution under trickle irrigation showed more regularity than other types due to root distribution relative to the placement and the number of irrigation distributors. The net effect of trickle-irrigation was to increase water saving for producing one kilogram of olive fruits with 18% less than with bubblers. The number of fruits increased under trickle irrigation by 16% while the olive tree yield (kg/tree) increased by 18% compared with bubblers respectively.

Wilde et al. (2009) studied a field of installation subsurface drip irrigation (SDI) systems at Texas, USA to record the agronomic effects of uniformities distribution on cotton production over six years. NPVs were evaluated for each level of irrigation and uniformity. At the lower irrigation level, the study concluded that the least uniform design provided a higher NPV. Further, the length of the scheduling horizon influenced NPV with the more uniform system due to the cumulative effect of small enhancements in net income over a longer time. Besides, the producer's risk aversion (RA) level influenced their choice of design uniformities. A more RA producer excelled in a more uniform design and was willing to pay a higher installation cost for a more uniform system. A less RA producer preferred a less uniform system design with a lower initial cost.

A subsurface drip irrigation (SDI) system was used by Soussa (2010) to investigate the suitable irrigation water schemes in open fields and greenhouse for tomatoes and peppers. The study investigated the effects of soil form and climate on consuming water. Two Enviroscan sensors were composited to measure the soil moisture. Further, two weather stations were held to measure the climate parameters. The crop evapotranspiration and the amount of irrigation water were estimated using software based on the Penman-Monteith approach. The climate and crop growth parameters,

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and the crop water use were estimated. These estimated values were used to develop a suitable scheme for water use and crop production. The results showed a significant increase in crop productivity by 18% when the suggested SDI system is used over the normal drip irrigation system.

Kumar and Palanisami (2010) studied impacts of drip irrigation on the farming system in terms of cropping patterns, resources use and yield. The study showed that the adoption of drip irrigation technology has increased the net sown area, net irrigated area, and thereby has supported in obtaining higher cropping consistency and irrigation intensity. The results suggested that a valuable move towards crops such as coconut, grapes, and banana from annual crops like vegetables, sugarcane. The main causes have been found as a shortage of human labor and water. The analysis of the economics of crop farming under drip has detected that the drip method of irrigation has an important impact on resource-saving, cost of cultivation, yield of crops, and farm profitability. The physical water and energy productivity is importantly high in the drip over the other methods of irrigation.

A 4-year study was conducted by Ehret et al. (2012) to set the effects of drip irrigation configuration and rate on fruit yield and quality of young highbush blueberry plants. Plants were grown in a silt loam soil on raised beds and were non-irrigated or irrigated using either one or two lines of suspended drip strip. Each laterals' configuration had emitters spaced every 0.3 or 0.45 m. Water was supplied by each drip configuration for two rates, a moderate of 5 L/plant, and a heavy of 10 L/plant each per irrigation episode. Neither the number of irrigation lines nor emitter spacing had an impact on yield or fruit quality. The yield was not affected by irrigation rate until the fourth year after planting and with only 5 L/plant. The yield increase was the result of differences in fruit weight during the second of two harvests and was associated with delays in fruit maturation.

Narayanamoorthy and Devika (2017) studied the economic and resource impacts of drip irrigation including its benefit-cost pattern using survey data in crops like okra. The study found that the use of drip irrigation can reduce 15% of cultivation cost, save 47% of water resources and electrical energy, and increase 49% of the productivity of okra for the same cultivated area under the traditional method of irrigation. Farmers cultivating okra under using the drip irrigation showed that an additional farm business income of RS 72,711 per acre over the non-drip adopters.

Dhehibi et al. (2018) studied the effect of subsurface drip irrigation (SDI) at the rate of 60% 40% and 20% of water requirement on the date palm productivity and water use efficiency. The water quantity could be reduced using SDI at rates of 20%, 40%, and 60% of water demands, respectively. Thus, the yield of the date palm is for 2.0, 2.7, and 4.7 kg/m^3, respectively. The economic evaluation suggested that using SDI at the rate of 60% of water requirements, the net profit was US$12825/ha.

The economic analysis of high-efficiency irrigation systems in Pakistan have been conducted by Razzaq et al. (2018). The water productivity of modern and conventional-irrigated farms have been observed and compared. The wheat crop used the water of sprinkler systems while mango orchards used the drip irrigation systems. Economic analysis of benefit-cost ratio (BCR) and net present value (NPV) revealed that the installation of sprinkler and drip irrigation systems were an economically feasible option. Further, the productivity of conventional farms was less than those of modern ones.

El-Attar et al. (2019) studied the effect of the irrigation system and the number of drippers on yield, fruit quality, chlorophyll and leaf mineral content of mango trees which grown under conditions of sandy soil were watered with 6, 9, or 12 drippers for each tree, either as a surface or subsurface of irrigation system. The obtained results indicated that the subsurface irrigation system was more effective than the surface one. The drippers' number showed different effects concerning yield per tree or the fruit's quality and the leaf mineral content. From one hand, it could be concluded that the trees which were irrigated with 9 subsurface drippers save the irrigation water without a significant decrease in the yield compared to the control (12 drippers as the surface irrigation). On the other hand, as a subsurface dripper irrigation system, the highest significant yield as kg/tree was obtained due to 12 drippers/tree compared with the 9 or 6 drippers/tree.

García et al. (2020) reviewed the current irrigation scheduling methodologies based on two case studies (woody and field crops) located in semi-arid areas. The preferable irrigation program had been noticed requiring good investment for equipment, operation, and maintenance services. These approaches could be suitable for the low availability of water and profited highly.

Khalifa (2020b) conducted the economic analysis on seven crops and nine vegetables using the trickle irrigation system in a hypothetical field in Egypt based on the physical and economic conditions. Economic analysis measures of benefit-cost ratio (B/C) and net return values $(\mathrm{B}-\mathrm{C})$ were estimated. The crops considered in the study were: sugar beet, lupine, lentil, chickpea, soybean, sesame, and peanuts. Also, the concerning vegetables were tomato, onion, garlic, peas, cabbage, eggplant, watermelon, cantaloupe, and cowpea. Some convenient rotations for the crops and vegetables were presented. The study results showed that high values of net returns were attained for most crop rotations. Further, most of B/C for crop rotations have been ranged between 1.5 and up to more than 2.0. These estimated results corroborated that investment in trickle irrigation could be economically highly viable for arid arable lands such as Arab countries.

However, the major scopes of drip irrigation appear to be in fruit crops where the system can provide a substantial water economy and better productivity. Further, the cost of the system will be reasonable, economical, and viable. Indeed, drip irrigation is highly convenient for all wide-spaced crops. Drip irrigation is very useful in fruit crops, but the information on the economic viability of this system is lacking. Therefore, the objective of this study was to determine the effect of a drip irrigation system with different configurations on different economic bases such as; fixed costs, labor cost, energy cost, maintenance cost, the net return, and benefit-cost ratio for long-life fruit trees.

2. MATERIALS AND METHODS

This study used the model of trickle irrigation system design (TISD) developed by Khalifa (2020a) to design the trickle irrigation system with the economic analysis deliberated by Khalifa (2020b) to estimate the impact of drip irrigation system on several bases of economic agronomy. These economic bases include fixed costs, labor cost, energy cost, maintenance cost, the net return, and benefit-cost ratio. This study applied to long-life fruit trees (apples, apricots, bananas, citrus, dates-palm, figs, grapes, guavas, mangoes, olives, and pears).

2.1 ECONOMIC ANALYSIS

All the economic analysis for this study was referred to Khalifa (2020b). By summing the main bases of these analyses, the total annual costs of trickle system are the sum of annual costs' components on account for capital (construction elements of drip system including outlets, regulator, laterals, manifolds, mainlines, fittings, and pump and raw land costs), plantation and labor costs, energy costs, maintenance costs, production costs (including; land preparation, seeding, fertilization,

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weeding, pest control, and harvesting), water and taxes (if any), and equivalent annual cost component of first years' costs. Also, net returns are estimated by subtracting the above estimated average total annual costs (C) from the average annual gross returns (B). If the economic goal is to maximize net return, then the system with the largest net return $(B - C)$ meets the goal based on the economic analysis. Further, the B/C ratio is considered an important criterion of economic analysis. If the goal is to maximize the return on investment, then the system that yields the highest B/C ratio best meets the goal based on the economic analysis. It is possible, even common, to have one system yield the largest net return and another has the highest B/C ratio.

The final selection of the drip irrigation system, usually, reduces the system and configuration that either returns the greatest net benefits $(B - C)$ or provides the best return on investment (B/C) depending upon the goal selected. After the system and configuration have been selected and designed, the project should be presented by preparing plans, schedules, and instructions for proper layout. Plans must show the pump position, network alignment, laterals' position, and strips, and roads' dimension. The schedules should list the necessary information about crops, weather, soil, irrigation, system components, costs, and expected benefits from the project. Generally, final selection should not be made by the designer alone but presented to the owner and operator and the decision made jointly.

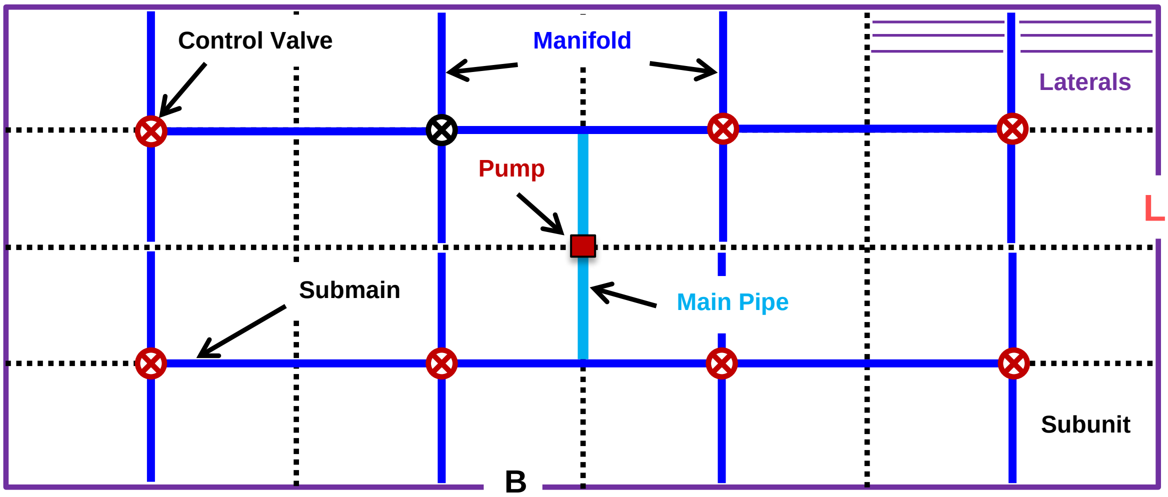

Figure 1: Configuration #1 for Drip Irrigation System (Khalifa, 2020a).

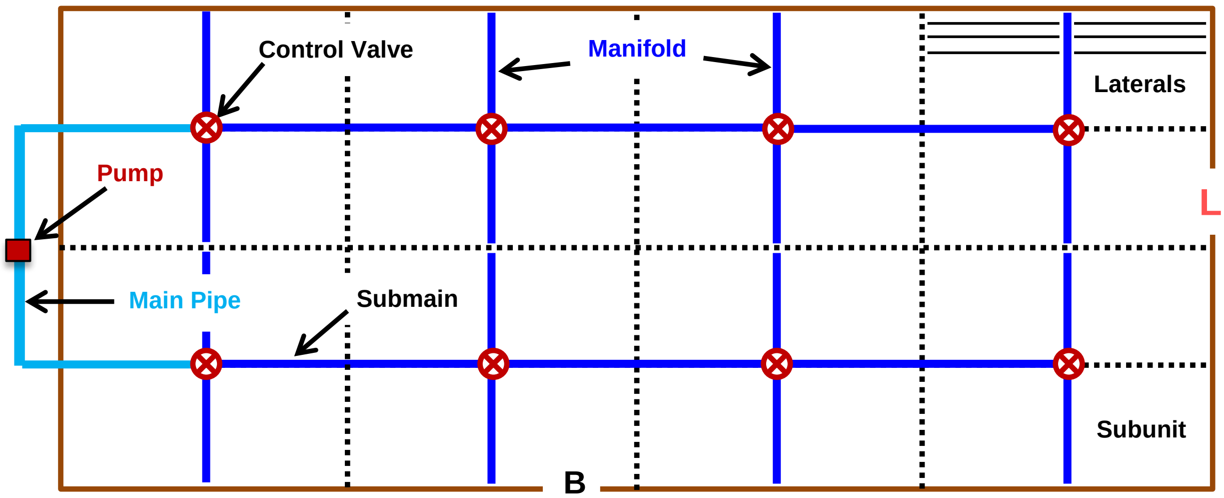

Figure 2: Configuration #2 for Drip Irrigation System (Khalifa, 2020a).

2.2 DRIP IRRIGATION MODEL DEVELOPMENT

The trickle irrigation system design (TISD) model developed by Khalifa (2020a) and redeveloped by Khalifa (2020b) to consider the economic analysis is used to estimate the effects of the drip configurations and laterals' direction according to the North on the economic bases of long-life fruit trees. Thus, the economic analysis should be linked with TISD to consider the most economic size for different pipe reaches of laterals, manifolds, and main pipe. The most economical pipe size gives the minimum sum of fixed cost (material) and energy cost (power). The used pipe material depends on the landowner's needs and used system. For manifolds and main pipe network of the drip irrigation system; PVC pipe is usually used, and must satisfy the installation and operating conditions. The most economic pipe size selection is based on many parameters: desired rate of interest by the developer; pipe material and its life cycle; equivalent annual rate of energy inflation; pump efficiency; fuel cost per unit of brake power output (Bliesner and Keller, 1982); pipe price; and the system capacity. Thus, this study used the two common configurations, see Figures 1 and 2. Each system configuration, the laterals' direction may be parallel to the farm width (parallel North, PN) or the farm length (normal North, NN). Figure 3 shows the flowchart for developing the TISD model.

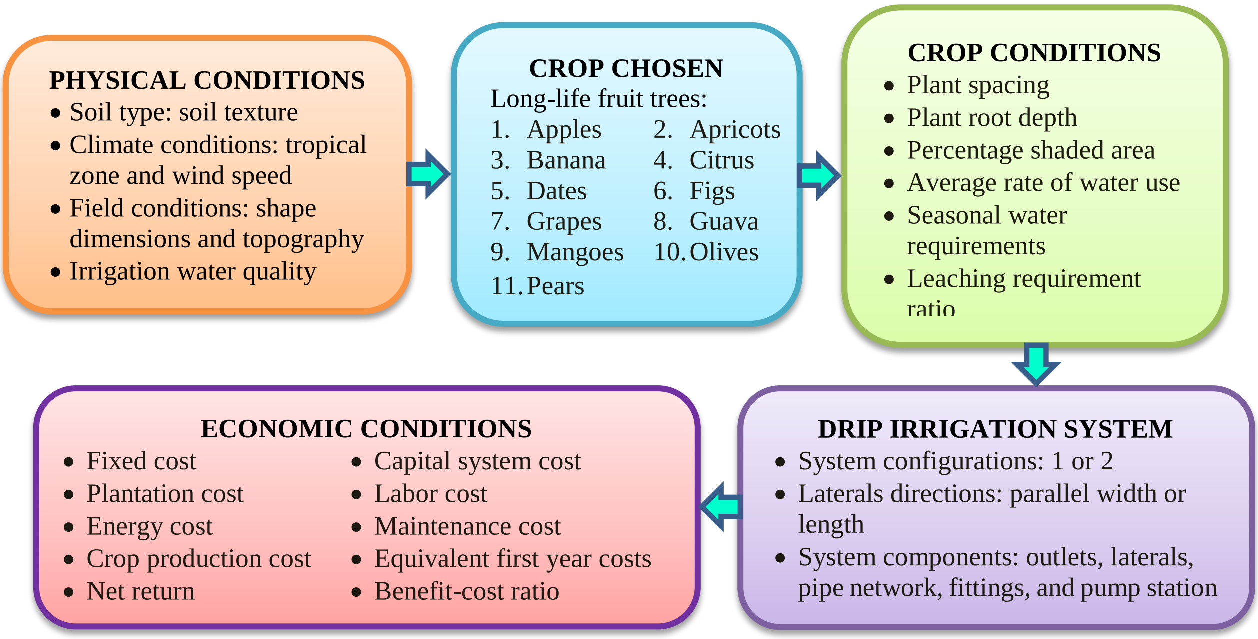

Figure 3: Flowchart of developing the Trickle Irrigation System Model (TISD).

2.3 CASE STUDY

A hypothetical farm in Egypt as shown in Figure 4 was studied by the developed model TISD to show the physical, crop, and economic conditions (see Table 1).

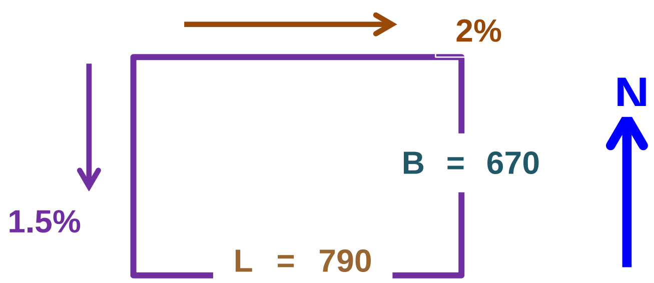

Figure 4: Farm shape and topography of the case study (Khalifa, 2020b).

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Table 1: Site physical, crop, and economic data of the case study

Physical and Crop Conditions		
Soil type:	Coarse texture (coarse or fine or loamy sands)	
Climatic conditions:	Hot climate (Middle Egypt) Wind speed = 3.0 mph	
Farm shape:	Figure 4	
Farm topography:	Figure 4	
Crop conditions:	Plant spacing Plant root depth Percentage shaded area The average rate of water use Seasonal water requirements Leaching requirement ratio	Doorenbos and Pruitt (1992) SCS (1993) Sawa and Frenken (2002) Steduto et al. (2012) Reddy et al. (2017)
Obstructions:	No	
Water source:	Surface water Suction head = 6.0 m Water quantity = no restriction Frequency = continuous Water quality, Electrical Conductivity = 640.0 ppm = 1.0 dS/m Water price = 0.0 US$/$m^3$	
Economic Conditions		
Raw land value:	RAW = 1000 US$/ha	
Real interest rate:	RIR = 6.0%	
Nominal interest rate:	NIR = 10.0%	
Electric energy:	Energy cost = 0.10 US$/kW-hr. (for 2018 prices) Energy escalation rate = 27.0% (for 2018 prices) https://eipr.org/en/publications/electricity-facts-20172018-price-hikes-continue	
Labor:	Available and reliable Labor cost = 4.5 US$/man-hr. (for 2018 prices) Labor escalation rate = 5.0%. (for 2018 prices) https://www.capmas.gov.eg/HomePage.aspx	
Construction elements:	Available for drip irrigation system Available maintenance supports PVC specification = DIN (Germany) PVC price = 15 US$/kg of PVC (for 2018) Aluminum and steel pipe (Keller and Bliesner, 1990) Outlets' prices (Rain Bird, 2018)	

Based on the agricultural statistics in Egypt (FAOSTAT, http://www.fao.org/faostat/en), the required information of the concerned long-life fruit trees in 2018 is listed in Table 2.

Table 2: Economic information of concerned long-life fruits for the case study (FAOSTAT, 2018)

Fruit trees	Fruit production price (US$/ha)	Average fruit production (ton/ha)	Average fruit price (US$/ton)*
Apples	4707.4	25.09	187.6
Apricots	4174.2	15.43	270.6
Bananas	13295.9	46.44	286.3
Citrus	3726.2	24.11	154.55
Dates-palm	5253.4	31.76	165.4
Figs	1336.2	6.59	202.8
Grapes	5158.9	22.31	231.2
Guavas	1473.6	14.78	99.7
Mangoes	2697.8	6.78	397.9
Olives	3135.2	10.41	301.1
Pears	3702.6	15.89	233

*FAOSTAT (2017)

3. RESULTS AND DISCUSSION

According to the physical, crops, and economic data site conditions, the developed model (TISD; Khalifa (2020a, 2020b) was run for all selected long-life fruit trees under the point-source drip irrigation system with the two common configurations shown in Figures 1 and 2 according to the shape of case study shown in Figure 4. Table 3 listed the summary of the model designs for long-life fruit trees. After completing the system design trails and their economic analysis, TISD selects the most economic design based on the maximum B/C ratio.

The expected system costs and returns were also calculated by the model. The listed parameters in Table 3 are as follow:

1. The present worth capital (fixed) cost per unit area of the farm, (US$/ha);
2. The total annual costs per unit area of the farm, (US$/ha), which include: annual capital system cost (US$/ha); annual capital raw land cost (US$/ha); annual plantation cost (US$/ha); annual labor cost (US$/ha); annual energy cost (US$/ha); annual maintenance cost (US$/ha); annual crop production cost (US$/ha).
3. The net cultivated area under point-source drip irrigation system (ha);
4. The expected annual net return per unit area of the farm, (US$/ha); and
5. The expected B/C ratio from the project.

For long-life trees, the first years of agriculture (from 3-7 years according to the trees' type) there is no normal production. Therefore, the first years' costs were calculated by the model as a present worth and redistribution over the project life. So, the total annual costs include the equivalent annual cost component of the first years' costs before full production. From Table 3, the best conditions of long-life trees, based on a drip irrigation system, system configurations, and laterals' directions could be obtained. These conditions could be selected based on different selection bases. The considered selection bases are; maximum B/C ratio, the maximum net return, maximum net cultivated area, minimum fixed cost, minimum total annual costs, minimum annual energy cost, minimum annual labor cost, and minimum annual maintenance cost. Then, the landowner can select suitable conditions for him. Table 4 lists the best conditions of the type of fruit, system configurations, and laterals' directions based on different selection bases.

Table 3: Summary of TISD model of the case study for long-life fruit trees

Fruit trees	Configuration and lateral direction	Fixed cost (US$/ha)	Total annual costs (US$/ha)									Net area (ha)	Gross return (US$/ha)	Net return (US$/ha)	B/C
			System	Land	Plantation	Labor	Energy	Maintenance	Production	Equivalent 1st years	Total				
Apples	PN1	721	75	27	86	4	196	12	2306	593	3300	51.45	4576	1276	1.39
	PN2	768	75	27	88	4	182	12	2355	602	3345	52.54	4673	1328	1.40
	NN1	631	60	27	87	4	180	10	2351	596	3316	52.46	4666	1349	1.41
	NN2	899	92	27	84	4	187	13	2238	581	3226	49.94	4441	1216	1.38
Apricots	PN1	509	52	17	56	2	135	8	1191	502	1963	52.04	4104	2141	2.09
	PN2	507	51	17	56	2	136	8	1191	502	1963	52.04	4104	2141	2.09
	NN1	383	41	17	56	2	113	7	1191	489	1916	52.04	4104	2188	2.14
	NN2	600	62	17	53	2	123	9	1143	485	1895	49.94	3938	2043	2.08
Bananas	PN1	1764	192	40	554	14	443	29	6137	1641	9051	51.79	13010	3959	1.44
	PN2	1745	189	40	554	14	411	29	6137	1632	9008	51.79	13010	4002	1.44
	NN1	1200	153	40	558	14	382	25	6187	1627	8986	52.21	13115	4129	1.46
	NN2	2087	219	40	558	14	393	32	6187	1649	9092	52.21	13115	4023	1.44

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Table 3: Summary of TISD model of the case study for long-life fruit trees (continue)

Fruit trees	Configuration and lateral direction	Fixed cost (US$/ha)	Total annual costs (US$/ha)									Net area (ha)	Gross return (US$/ha)	Net return (US$/ha)	B/C
			System	Land	Plantation	Labor	Energy	Maintenance	Production	Equivalent 1st years	Total				
Citrus	PN1	350	38	20	25	2	155	7	1667	650	2563	52.75	3714	1151	1.45
	PN2	346	38	20	25	2	173	7	1667	657	2588	52.75	3714	1126	1.44
	NN1	526	42	20	25	2	181	7	1651	656	2582	52.25	3678	1096	1.42
	NN2	634	62	20	25	2	189	9	1643	665	2614	52	3661	1047	1.40
Dates	PN1	458	49	27	221	3	140	8	1462	667	2577	52.04	5165	2588	2.00
	PN2	798	80	27	216	3	161	11	1427	674	2600	50.78	5040	2440	1.94
	NN1	682	55	27	219	3	168	9	1446	673	2600	51.45	5107	2507	1.96
	NN2	849	82	27	207	3	165	11	1375	656	2527	48.93	4856	2329	1.92
Figs	PN1	255	29	13	17	1	45	5	879	337	1327	52.21	1318	-9	0.99
	PN2	252	29	13	17	1	51	5	879	339	1335	52.21	1318	-17	0.99
	NN1	369	32	13	16	1	53	5	872	338	1332	51.79	1307	-24	0.98
	NN2	449	45	13	16	1	50	7	851	336	1318	50.53	1276	-43	0.97
Grapes	PN1	806	77	24	83	2	141	13	2173	551	3063	51.32	5002	1939	1.63
	PN2	849	86	24	83	2	123	13	2157	546	3034	50.95	4966	1932	1.64
	NN1	799	79	24	83	2	141	13	2191	556	3088	51.74	5043	1955	1.63
	NN2	995	103	24	83	2	124	15	2191	559	3101	51.74	5043	1942	1.63
Guavas	PN1	213	24	11	21	1	84	4	714	294	1154	52.21	1454	300	1.26
	PN2	210	24	11	21	1	96	4	714	298	1170	52.21	1454	283	1.24
	NN1	307	27	11	21	1	99	4	709	299	1171	51.79	1442	271	1.23
	NN2	375	37	11	20	1	93	6	691	295	1155	50.53	1407	252	1.22
Mangoes	PN1	170	17	11	18	0	34	3	923	449	1455	51.87	2644	1189	1.82
	PN2	165	17	11	18	0	38	3	923	450	1460	51.87	2644	1184	1.81
	NN1	262	19	11	18	0	41	3	909	447	1449	51.11	2605	1156	1.80
	NN2	318	30	11	17	0	42	4	882	442	1428	49.6	2528	1100	1.77
Olives	PN1	268	29	15	26	1	76	5	1295	647	2095	52.75	3125	1030	1.49
	PN2	265	29	15	26	1	85	5	1295	651	2107	52.75	3125	1017	1.48
	NN1	403	32	15	25	1	89	5	1283	650	2100	52.25	3095	995	1.47
	NN2	486	47	15	25	1	93	7	1277	658	2123	52	3080	957	1.45
Pears	PN1	398	36	16	33	2	110	6	1350	339	1891	51.66	3614	1723	1.91
	PN2	486	46	16	31	2	104	7	1290	328	1824	49.39	3455	1631	1.89
	NN1	331	28	16	34	2	95	4	1378	340	1897	52.75	3690	1793	1.95
	NN2	470	43	16	33	2	92	6	1337	334	1862	51.16	3579	1717	1.92

Table 4: Best design conditions based on different selection bases

Best conditions / Selection bases	Fruit trees	System configurations	Laterals' direction
Maximum B/C ratio	Apricots and Dates	#1 & #2	PN or NN
Maximum Annual net return	Bananas	#1 & #2	PN or NN
Minimum Initial capital cost	Guavas and Mangoes	#1 & #2	PN
The maximum Net cultivated area	Citrus and Olives	#1 & #2	PN
	Pears	#1	NN
Minimum Total annual costs	Figs, Guavas, and Mangoes	#1 & #2	PN or NN
Minimum Energy cost	Figs and Mangoes	#1 & #2	PN or NN
Minimum Labor cost	Mangoes	#1 & #2	PN or NN
Minimum Maintenance cost	Mangoes	#1 & #2	PN or NN

From the previous analysis that applying the work of case study to design a certain project, a lot of time and effort is required. To reduce the required time and effort, a simple manual method is proposed to select the most promising configurations of a drip irrigation system for each specific site based on the desired economic goal. This method reduces the alternatives that should be designed by the TISD model to select the best configuration. Therefore, a parametric study should be conducted to discuss the effects of different long-life fruit trees on the different costs and returns of common systems, configurations, and possible laterals' directions. So, the TIDS model was run for the long-life trees (Table 2) under the drip irrigation system configurations by using the physical and economic data (Table 1).

The selection basis of the drip irrigation system configurations and laterals' direction refers to the landowner. This basis may be one of the following factors:

1. Maximum B/C ratio or maximum net return or maximum net cultivated area.
2. Minimum initial capital cost or minimum total annual costs or minimum annual operating and maintenance costs.

3.1 EFFECT OF DRIP IRRIGATION SYSTEM ON MAXIMUM ECONOMIC BASES

Figures 5, 6, and 7 show the calculated B/C ratios, the annual net return, and net cultivated area, respectively of the chosen trees (Table 2) under the drip irrigation system configurations and laterals' direction on the North. From Figures 5, 6, and 7, the best laterals' direction may be parallel to or normal on the North. There is an insignificant effect of the system configuration and lateral lines' direction with farm sides or North on the B/C ratio (Figure 5). There is also no significant effect of the system configuration and lateral lines' direction with on net returns (Figure 6). From Figure 7, the system's configuration type has a small effect (around 5 %) on the net cultivated area. So, it could be considered that the B/C ratio, the net returns, and the net cultivated area are approximately the same trends with respect to the drip system configurations and laterals' direction to the North. Also, it could be noticed that the arrangements of the long-life fruit trees based on all the maximum of B/C ratio, the annual net return, and net cultivated are different (see Table 5). Thus, the B/C ratio, annual net return, and the net cultivated area are not always the same selection basis. In other words, the fruit trees that give maximum B/C ratio not always give maximum net return or maximum net cultivated area.

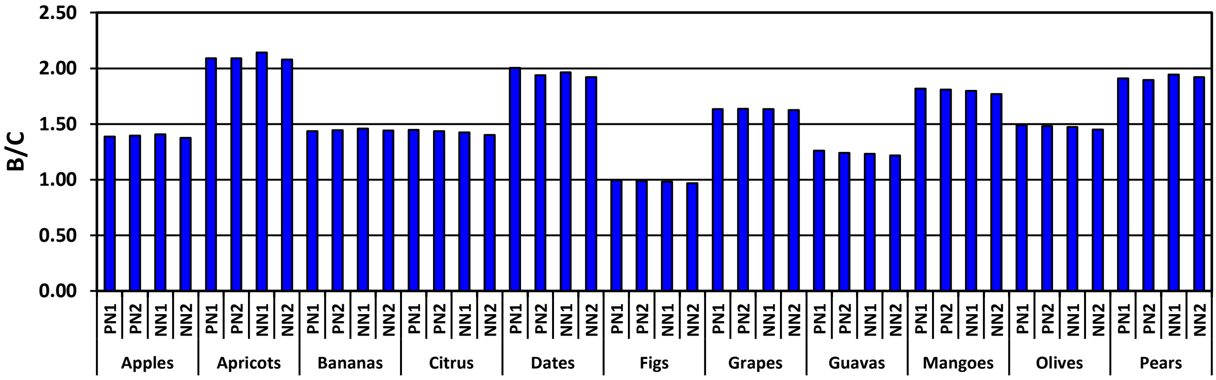

Figure 5: B/C Ratios of chosen long-life fruit trees under drip irrigation and configurations.

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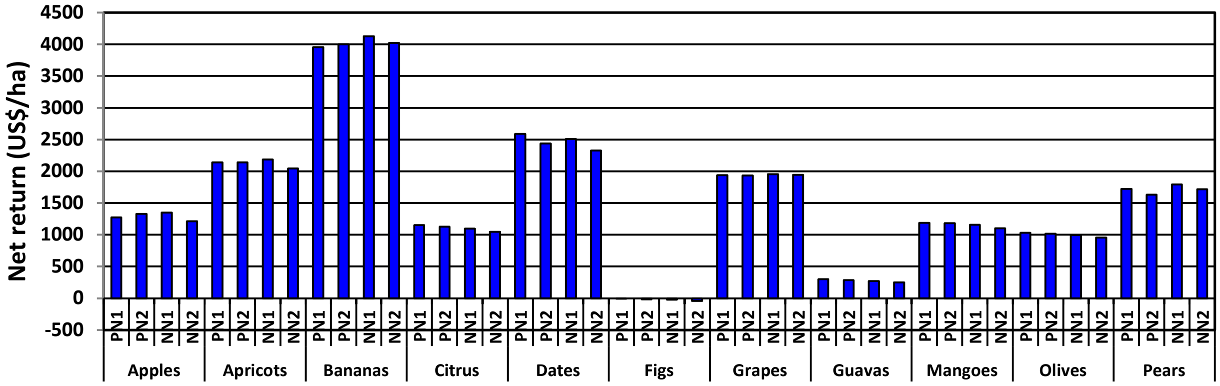

Figure 6: Annual Net Return of chosen long-life fruit trees under drip irrigation and configurations.

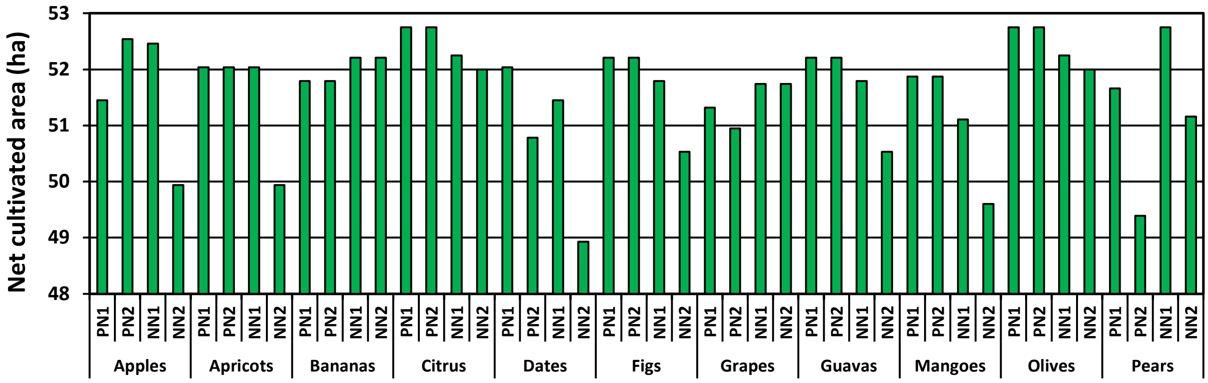

Figure 7: Net Cultivated Area of chosen long-life fruit trees under drip irrigation and configurations.

Table 5: Long-life fruits based on the maximum economic bases.

Fruit trees	Max. B/C Ratio		Max. Net Return		Max. Net Cultivated Area	
	Best configuration	Lateral's direction	Best configuration	Lateral's direction	Best configuration	Lateral's direction
Apples	#1 & #2	PN/NN	#1	NN	#2	PN
Apricots	#1 & #2	PN/NN	#1	NN	#1 & #2	PN
Bananas	#1 & #2	PN/NN	#1	NN	#1 & #2	NN
Citrus	#1 & #2	PN/NN	#1 & #2	PN	#1 & #2	PN
Dates	#1 & #2	PN/NN	#1	PN	#1	PN
Figs	#1 & #2	PN/NN	No	No	#1 & #2	PN
Grapes	#1 & #2	PN/NN	#1	NN	#1 & #2	NN
Guavas	#1 & #2	PN/NN	#1 & #2	PN	#1 & #2	PN
Mangoes	#1 & #2	PN/NN	#1 & #2	PN	#1 & #2	PN
Olives	#1 & #2	PN/NN	#1	PN	#1 & #2	PN
Pears	#1 & #2	PN/NN	#1	NN	#1	NN

3.2 EFFECT OF DRIP IRRIGATION SYSTEM ON MINIMUM ECONOMIC BASES

Figure 8, 9, 10, 11 show the calculated total annual costs, initial capital cost, annual energy cost, and annual maintenance cost, respectively of the chosen trees (Table 2) under the drip irrigation system configurations and laterals' direction on the North. The total annual costs are the summation of; equivalent annual system and land costs, annual operation cost (energy, labor, and maintenance), annual average production cost, and the equivalent annual cost of long-life trees for years' preparation before full production. From Figure 8, it could be noted that the total annual costs for the chosen fruit trees have nearly insignificant effect with the two configurations and laterals' direction. Further, from Figure 9, it could be noticed that system configurations type and laterals' direction have a very high effect on the initial installation cost, especially for Bananas (around 50%). Furthermore, from Figure 10, it could be noted that the drip system configurations and laterals' direction have a high effect on the annual energy cost especially for Bananas (around 20%). From Figure 11, it could be noted that the drip system configurations have a considerable effect on the annual maintenance cost. Further, laterals' directions have a considerable effect on the annual maintenance except in Bananas (more 20% normal on the North). Also, the arrangements of the fruit trees are based on all the minimum of total annual costs, initial installation cost, annual energy cost, and annual maintenance cost are different (see Table 6). Therefore, the combination of the drip irrigation system configurations and laterals' direction that gives maximum net return and/or maximum B/C ratio, not necessary to require the minimum total annual costs, nor minimum initial installation cost, nor minimum annual energy cost, nor minimum annual maintenance cost.

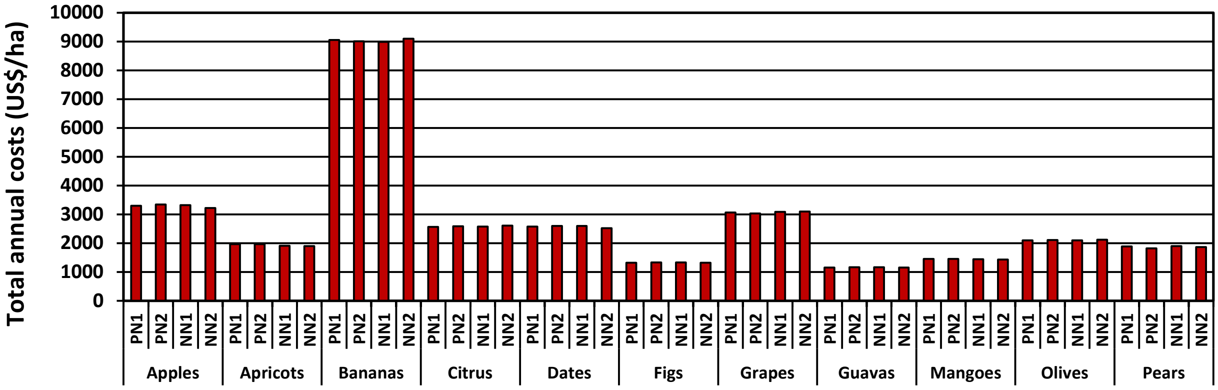

Figure 8: Total Annual Costs of chosen long-life fruit trees under drip irrigation and configurations.

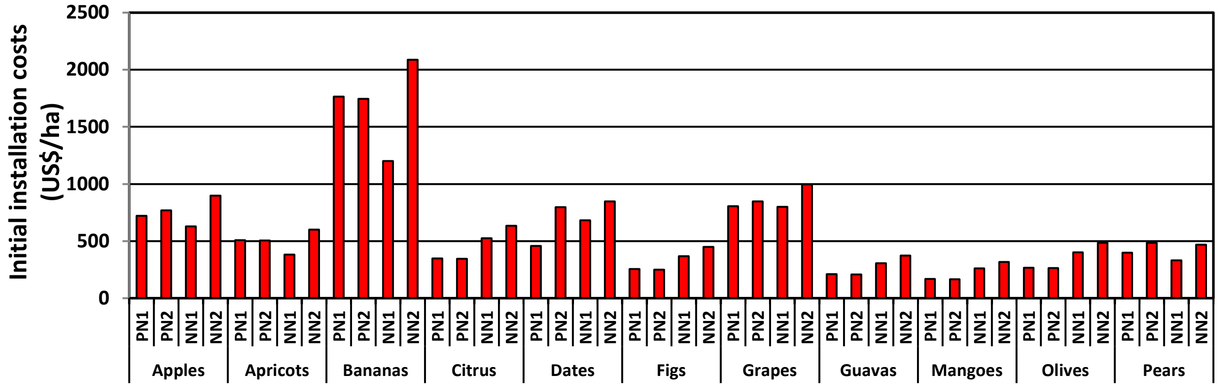

Figure 9: Initial Installation Cost of chosen long-life fruit trees under drip irrigation and configurations.

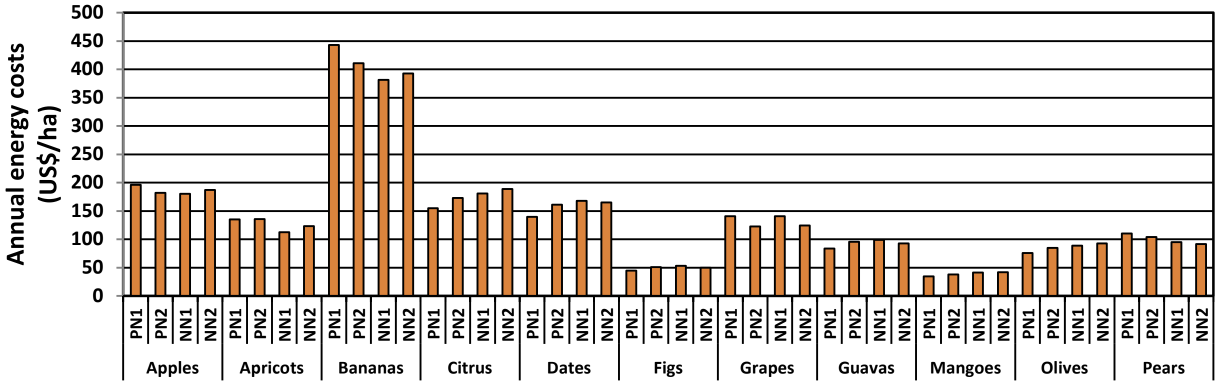

Figure 10: Annual Energy Cost of chosen long-life fruit trees under drip irrigation and configurations.

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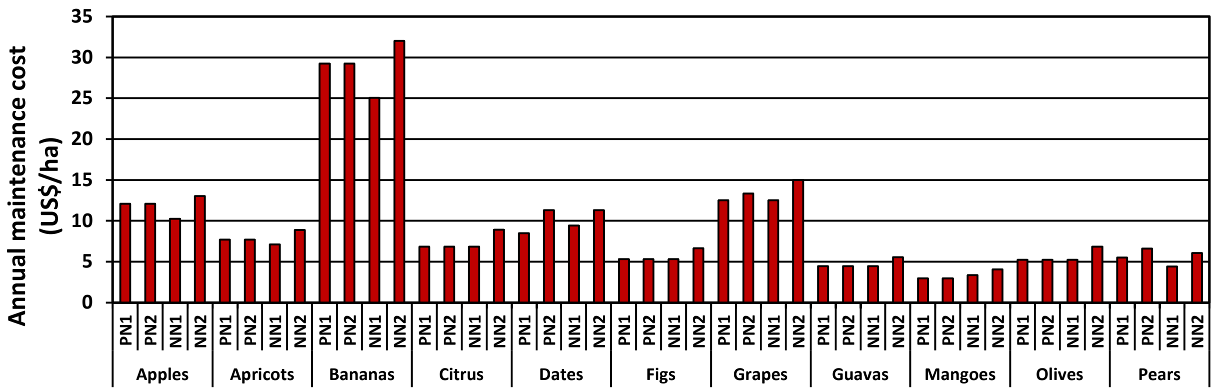

Figure 11: Annual Maintenance Cost of chosen long-life fruit trees under drip irrigation and configurations.

Table 6: Long-life fruits based on the minimum economic bases.

Fruit trees	Min. Total Annual Costs		Min. Initial Installation Cost		Min. Annual Energy Cost		Min. Annual Maintenance Cost	
	Best configuration	Lateral's direction	Best configuration	Lateral's direction	Best configuration	Lateral's direction	Best configuration	Lateral's direction
Apples	#1 & #2	PN/NN	#1	NN	#1	NN	#1	NN
Apricots	#1 & #2	PN/NN	#1	NN	#1	NN	#1	NN
Bananas	#1 & #2	PN/NN	#1	NN	#1	NN	#1	NN
Citrus	#1 & #2	PN/NN	#1 & #2	PN	#1	PN	#1	PN, NN
Dates	#1 & #2	PN/NN	#1	PN	#1	PN	#1	PN
Figs	#1 & #2	PN/NN	#1 & #2	PN	#1	PN	#1	PN, NN
Grapes	#1 & #2	PN/NN	#1	PN/NN	#2	PN	#1	PN, NN
Guavas	#1 & #2	PN/NN	#1 & #2	PN	#1	PN	#1	PN
Mangoes	#1 & #2	PN/NN	#1 & #2	PN	#1	PN	#1	PN
Olives	#1 & #2	PN/NN	#1 & #2	PN	#1	PN	#1	PN
Pears	#1 & #2	PN/NN	#1	NN	#2	NN	#1	NN

As mentioned earlier, the economic efficiency is central to the drip irrigation system. Development projects may focus on either the maximum B/C ratio or maximum net benefits from the development. Economic constraints may have an impact on economic efficiency and play an important role in selecting the system configurations type and their lateral's direction. The conducted analyses through this study were summarized and listed in Table 7. Table 7 lists the best arrangements of the drip irrigation system based on the desired selection basis and the cultivated long-life fruit trees. Also, Table 7 lists the significant effect of the selection of drip irrigation system configurations and laterals' direction.

Table 7: Effect summary of the drip irrigation system for long-life fruit trees on the economic bases.

No.	Selection Basis	Significance of system configurations	Significance of laterals' direction
1	B/C ratio	Very small (2%)	Negligible (< 1%)
2	Annual net return	Small (< 5%)	Small (< 5%)
3	Total annual costs	Negligible (< 1%)	Negligible (< 1%)
4	Net cultivated area	Small (< 5%)	Small (< 5%)
5	Initial capital costs	Very high (> 20%)	Very high (> 20%)
6	Annual Energy costs	High (< 20%)	High (< 20%)
7	Maintenance costs	Considerable (< 10%)	Considerable (< 10%)

4. CONCLUSION

It emanates from the findings of this study that the effect of the drip irrigation system with configurations and laterals' direction for long-life fruit trees on the economic bases was varied. The outcome of this study was, based on the computer model TISD (Trickle Irrigation System Design). The model had been used with long-life fruit trees (apples, apricots, bananas, citrus, dates-palm, figs, grapes, guava, mangoes, olives, and pears) to meet with a desired economic goal. Based on the conducted economic bases study, the system's configuration types of drip irrigation have varied effects on the B/C ratio, net returns, total annual costs, initial installation cost, maintenance cost, energy cost, and net cultivated area. Based on B/C ratio, annual net return, total annual costs, and net cultivated area, the drip irrigation system configurations and laterals' direction have a very small effect for the selected long-life fruit trees. Furthermore, based on initial capital costs and annual energy costs, the drip irrigation system configurations and laterals' direction have a very high effect on the selected long-life fruit trees. The drip irrigation system configurations and laterals' direction have a considerable effect on the annual maintenance costs. For the future extension of this study, the parametric study of (soil type, land slopes, high wind speed, climate, irrigation water quality, water source type, farm partition, nominal interest rates, raw land value, and energy and labor inflation) are suggested to be investigated their impacts on the B/C ratio of the drip irrigation system with different configurations and laterals' direction.

5. AVAILABILITY OF DATA AND MATERIAL

All relevant data are already included in this article.

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