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AN ECONOMIC ANALYSIS OF CROPS PRODUCTION USING A TRICKLE IRRIGATION SYSTEM

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ABSTRACT

Rising water scarcity in many parts over the world especially in Arab countries needs increased water productivity to support the current agricultural production levels. Trickle irrigation system introduced relatively recently in Arab countries such as Egypt has proved to save substantial water and boost crops' productivity. This study performs 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 ($B - C$) were estimated. The crops considered in the study were: sugar beet, lupine, lentil, chickpea, soybean, sesame, and peanuts. Besides, the concerning vegetables were: tomato, onion, garlic, peas, cabbage, eggplant, watermelon, cantaloupe, and cowpea. The study presented some suitable growing rotations among the crops and vegetables. This study results showed that higher 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 is economically highly viable for arable lands such as Arab countries.

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

1. INTRODUCTION

Most irrigation development projects seek a maximum economic return. For economic efficiency, a project may focus on their maximum return on investment (B/C ratio) or maximum net benefits from the development ($B - C$). The difference between these goals is shown in Keller et al. (1988). The economic data required for economic analysis fall into two general categories, site-dependent and system-dependent (Keller and Bliesner, 1990). Site-dependent economic

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parameters include; interest rate; labor costs; energy costs; energy inflation factor; general inflation factor; property taxes (on equipment); water costs; the land value; and the return to irrigation for each crop. Interest rates are categorized as real or nominal. The nominal rate is the current rate of interest charged by the lending institution that will provide the credit and includes an inflationary component and risk, management, and profit component. The real rate (inflation-free and ranges from 5 to 7 %) is used to determine the annualized cost of capital expenditures that tend to appreciate, such as land values and permanent improvement to the land, like land-leveling. The nominal rate is used to determine the annualized cost of capital expenditures that depreciate or reach technical obsolescence with little or no salvage value. The energy inflation factor is the expected inflation rate for energy over the system's economic life and is important for balancing capital and operating costs. Inflation factors should be included for other input costs, such as labor and water. System-dependent parameters include system component costs; system component lives; and labor, energy and maintenance costs. The physical life of some components may be longer than the expected technical life due to the obsolescence of irrigation technology. In such cases, it is practical to use an expected economic life equal to the technical life rather than the full physical life.

Theoretical and applied investigations were carried out by Uzunov and Birkov (1994) to assess economic parameters and performance of trickle emitters, by analyzing different systems, and over 1000 layouts, in terms of flow-pressure relationship, coefficient of variation of manufacturing tolerances, and crop coefficient.

A computer model was developed by Narayanan et al. (1998) for the design, optimization, and economic analysis of drip systems for efficient irrigation of high profitable crops (carrots, cabbages, onions, and maize) in northern USA. Optimization of distribution lines reduced the total costs of the system by 10-50% compared to other possible design alternatives analyzed. The cost per acre was highest for a 1-acre system with four irrigation zones, and least for a 10-acre system with four zones.

DRIPCAD was developed by Reddy et al. (2000), to design a trickle system based on emission uniformity and the annual cost of the system as criteria for selection of the design. The design problem was illustrated through an example for a banana crop grown on a 6 ha area in India. The design optimizes for better economical design with varying main lines pipe sizes instead of design with uniform pipe size or higher uniformity.

Tiwari and Reddy (1997) studied planting geometry pattern effects on yield, capital cost, operating cost and net return for banana crop irrigated using a trickle irrigation system in the one-hectare area. The net return analysis was established to be maximally for one plant at a place of 2-m spacing. The length to width ratio of planting has a large correlation with the initial capital cost and the total annual cost. The highest return was acquired at 4-m spacing with two plants per point.

Luhach et al. (2004) examined the water-use efficiency and economic investment worth in sprinkler, drip, and surface irrigation systems in Haryana, India. The results have indicated significant water savings from sprinkler and drip irrigation methods. The sprinkler irrigation method has been obtained to reduce operational costs as well as labor requirements.

A field study of installation subsurface drip irrigation (SDI) systems was conducted at Texas, the USA by Wilde et al. (2009) to observe six-year agronomic impacts of distribution uniformities on cotton production. Net present values (NPV) were estimated for each uniformity level and irrigation level. The lower irrigation level, the least uniform design provided a higher NPV. Also, the length of the planning horizon affected NPV with the more uniform system having a better NPV at the longer planning horizon because of the cumulative effect of small improvements in net income over a longer time. The producer's risk aversion (RA) level affected the choice of design uniformities. A more RA producer preferred 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.

The study of Gravity drum kit drip (GDKD) irrigation system was evaluated by Mali and Kumar (2009) on economic water productivity, water, and labor-saving for cabbage and cauliflower cultivation. The results obtained were compared with the traditional furrow irrigation system. The GDKD irrigation system reduced the labor usage by an average value of 40.25% in cabbage and cauliflower cultivation as compared to the furrow system. In the GDKD system, the application of estimated amounts of water on a daily basis reduced the water usage to the extent of 36.4 % and 33.5 % in cabbage and cauliflower, respectively. The yields under the GDKD system were 42.86 % and 50.45 % higher than the furrow system of irrigation for cabbage and cauliflower respectively. Based on net income, GDKD's average economic water productivity was 152.45 RS/m^3 while that for the furrow system was 46.60 RS/m^3.

Kumar and Palanisami (2010) studied impacts of drip irrigation on the farming system in terms of cropping patterns, resources use and yield.. Using drip irrigation helps in the regions where scarcity of water and labor is scanty, as well as cultivation cost, crop yield, and farm profitability.

Narayanamoorthy and Devika (2017) studied the economic and resource impacts of drip irrigation including its benefit-cost pattern using crops survey data like okra in India. Using drip irrigation can reduce cultivation cost 15%, save water resources and electrical energy 47%, and productivity of okra increase 49% over the same crop cultivated under conventional flood method of irrigation. Okra farmers using the drip irrigation showed more farm business income of RS 72,711 per acre over the non-drip adopters.

Razzaq et al. (2018) conducted the economic analysis of high-efficiency irrigation systems in Pakistan, by measurement and comparison of the water productivity of modern and conventional-irrigated farms. The sprinkler irrigation system was mainly installed on the wheat crop while the drip irrigation systems were installed on mango orchards. The benefit-cost ratio (BCR) and net present value (NPV) showed that sprinkler and drip irrigation systems were an economically feasible option, as water productivity at modern farms was higher than those of conventional farms.

Montazar et al. (2019) explored the viability of drip irrigation for organic spinach production and the management of spinach downy mildew disease in California. Many combinations of dripline spacing and installation depths were assessed and compared with sprinkler irrigation as a control treatment and found that drip irrigation has the potential for producing organic spinach, conserve water, increase the efficiency of water use, and manage downy mildew.

In this study, the model of trickle irrigation system design (TISD) which was developed by Khalifa (2020) is used to conduct the economic analysis on seven crops and nine vegetables in a hypothetical field in Egypt based on the physical and economic conditions. The used economic analyses are the net returns and B/C ratio. The crops considered are sugar beet, lupine, lentil, chickpea, soybean, sesame, and peanuts. The concerning vegetables are tomato, onion, garlic, peas, cabbage, eggplant, watermelon, cantaloupe, and cowpea. The considered crops and vegetables use two rotations of growing in winter and summer.

2. METHODOLOGY

The economic analysis is most easily completed on an annualized basis. Therefore, total annual costs for the trickle irrigation system and its configurations and the returns for the grown crops should be computed. If the system of irrigation has markedly water-application uniformities, the yield impact should be estimated by Hill and Keller methods (1980). If yield expectations are not markedly, only the anticipated net return from each crop is required. This study used the model (TISD) which was developed by Khalifa (2020) to design the trickle irrigation system and can be extended to evaluate the economic analysis of irrigation.

2.1 ECONOMIC ANALYSIS

2.1.1 TOTAL ANNUAL COSTS

Total annual costs of trickle system (TAC), are the sum of annual costs' components due to capital, maintenance, energy, labor, production, and water and taxes (if any). The annual capital cost component is the sum of annual costs due to trickle system construction elements and raw land. Construction elements of the trickle system include outlets, regulators, laterals, manifolds, mainlines, fittings, and pumps. Initial capital cost for each element is estimated by multiplying the required quantity by its price per unit. Annual capital costs (ACC) are computed based on the capital recovery factor (CRF) (Pearson, 1974) for the life of the trickle irrigation system element (Bliesner and Merriam, 1988) and the nominal interest rate.

$$\text{ACC} = \sum[\text{CRF x Initial Equipment (Land) Cost}] \qquad (1).$$

The average annual maintenance costs (AMC) over the trickle system component's life should be considered in the analysis. The maintained system elements are pump, lateral, manifolds, and mainline. The typical list of maintenance costs expressed as a percentage of the original capital costs for major system components is included in (Bliesner and Merriam, 1988). The annual energy costs (AEC) could be obtained from the annual required energy and local energy price for the used power source. When the energy costs over the project life are annualized, they should be adjusted to account the expected inflation. The equivalent annual energy cost factor (EAE) can be computed as (Pearson, 1974)

$$\text{AEC} = \text{EAE x Unit Energy Cost x Annual Energy Use} \qquad (2).$$

Annual operating labor could be obtained from (Keller and Bliesner, 1990). The values reported are expected in man-hours per irrigation per hectare for in-season, and pre- and postseason for operation only without maintenance. Annual labor costs (ALC) are computed by using the listed time and local hour-cost. When comparing the large differences in labor needs, the expected inflation in labor costs should be accounted for. The equivalent annual labor cost (EAL) over the project life can be computed by Pearson (1974) with the expected labor inflation rate. Annual labor time is the sum of in-season and pre-and postseason times as

$$\text{In season time} = \text{Irrigation times/year x Required (man.hr/ha) x Area} \qquad (3),$$

$$\text{Pre season and postseason time} = 2 \text{ x Required (man.hr/ha) x Farm Area} \qquad (4),$$

$$\mathrm{ALC = EAL \; x \; Total \; Required \; (man.hr/year) \; x \; Labor \; Hour \; Cost} \qquad (5).$$

Other annual costs include taxes on equipment and water costs. The annual water cost (AWC) is computed as a function of the equivalent annualized water cost factor of inflation energy (EAW) as

$$\mathrm{AWC = EAW \; x \; Unit \; water \; cost \; x \; Gross \; water \; use/year} \qquad (6).$$

2.1.2 NET RETURNS

Net returns are computed by subtracting the above estimated average 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) best meets the goal based on the economic analysis. The $\mathrm{B/C}$ ratio is also computed by dividing the annual benefits by the annual costs. If the goal is to maximize the return on investment, then the system that yields the highest $\mathrm{B/C}$ 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 $\mathrm{B/C}$ ratio.

$$\mathrm{Gross \; return \; (B) = Crop \; yield \; (ton/fed) \; x \; Area \; (fed) \; x \; Price \; (L.E./ton)} \qquad (7)$$

$$\mathrm{Net \; return \; (B - C) = Gross \; returns - Total \; annual \; costs} \qquad (8)$$

$$\mathrm{B/C \; ratio = Gross \; return/Total \; annual \; costs} \qquad (9)$$

Final selection of the trickle 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.

2.2 DEVELOPMENT OF TRICKLE IRRIGATION MODEL

The model of trickle irrigation system design (TISD) which was developed by Khalifa (2020) is used to estimate the net return of planting the concerned crops. In this regard, one subroutine, namely (ECONOMIC) can be added to TISD to consider the most economic size for different pipe reaches of laterals, manifolds, and main pipe. The most economical pipe size is that 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 networks of the trickle irrigation system; PVC plastic material is usually used. Generally, the used pipe material must satisfy the installation and operating conditions. The most economic pipe size could be selected based on the following parameters: Desired rate of interest by the developer; Pipe material and its life cycle; Equivalent annual rate of energy escalation; Pump efficiency; Fuel cost per unit of brake power output (Bliesner and Keller, 1982); Pipe price; and The system capacity.

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2.3 CASE STUDY

A hypothetical farm in Egypt as shown in Figure 1 was studied by the developed model (Khalifa, 2020) to show the physical and economic conditions (see Table 1).

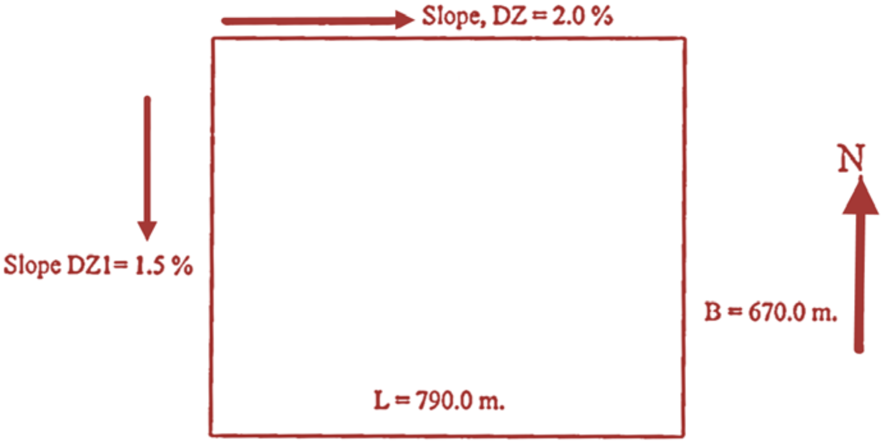

Figure 1: Farm shape and topography of the case study.

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

Physical Conditions	
Soil type:	Coarse texture (coarse or fine or loamy sands)
Climate conditions:	Hot climate (Middle Egypt), Wind speed = 3.0 mph
Water source:	Surface water, Suction head = 6.0 m, Electrical Conductivity = 640.0 ppm = 1.0 dS/cm, 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$/kW-hr. (for 2018 prices) Energy escalation rate = 7.0% (assumed)
Labor:	Labor cost = 4.5 US$/man-hr. (for 2018 prices) Labor escalation rate = 4.0%. (assumed)
Construction elements:	Available for trickle 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)

3. RESULTS AND DISCUSSION

Based on the above physical site conditions, the developed model (TISD; Khalifa, 2020), including ECONOMIC subroutine, proposes the suitable field crops and vegetables. These suitable plants are listed in Table 2. In this table, there are many crop rotations that could be composed. Some of these crop rotations are lupine-soybean or lupine-peanuts; lupine-sesame or lupine-eggplant or lupine-watermelon; sugar beet-soybean or sugar beet-sesame or sugar beet-peanuts or sugar beet-cantaloupe or sugar beet-cowpea; lentil-soybean or lentil-sesame or lentil-peanuts or lentil-eggplant or lentil-cantaloupe or lentil-cowpea; chickpea-soybean or chickpea-sesame or chickpea-peanuts or chickpea-eggplant or chickpea-watermelon or chickpea-cantaloupe; garlic-soybean or garlic-sesame or garlic-peanuts or garlic-eggplant or garlic-watermelon or garlic-cantaloupe or garlic-cowpea; peas-soybean or peas-sesame or peas-peanuts or peas-eggplant;

cabbage-soybean or cabbage-sesame or cabbage-peanuts; tomato-sesame; onion-sesame or onion-eggplant or onion-cantaloupe or onion-cowpeas.

Table 2: Proposed suitable crops based site conditions

Season	Field crops	Vegetables
Winter	1. Sugar beet. 2. Lupine. 3. Lentil. 4. Chickpea.	1. Tomato. 2. Onion. 3. Garlic. 4. Peas. 5. Cabbage.
Summer	1. Soybean. 2. Sesame. 3. Peanuts.	1. Tomato. 2. Onion. 3. Eggplant. 4. Watermelon. 5. Cantaloupe. 6. Cowpea.

The suitable irrigation system for these crops is the line-source of the trickle irrigation system with the two configurations shown in (Khalifa 2020). Based on the agricultural statistics in Egypt (FAOSTAT, http://www.fao.org/faostat/en), the required information of the concerned crop rotations in 2018 are listed in Table 3.

Table 3: Economic information of concerned crops for a case study (FAOSTAT, 2018)

Crop	Crop production cost (US$/ha)	Expected average crop production (ton/ha)	Average crop price (US$/ton)
Sugar beet	2068.47	51.2251	30 (40.38)[*]
Lupine	1026.86	2.0488	501.2
Lentil	1463.69	2.2546	649.2
Chickpea	373.1	2.187	170.6
Soybean	964.16	3.2	301.3
Sesame	1183.84	1.2941	914.8
Peanuts	4309.69	3.19[**]	1351[***]
Tomato	4064.11	40.9689	99.2
Onion	3952.09	36.291	108.9
Garlic	3739.48	22.3921	167
Peas	572.55	1.8772	305
Cabbage	2281.36	30.4587	74.9
Eggplant	3284.68	30.0795	109.2
Watermelon	3122.21	32.2876	96.7
Cantaloupe	2012.96	27.1288	74.2
Cowpea	2187.96	9.8468	222.2

[*]Abdi et al. (2019), [**]Barghash et al. (2014), [***]http://www.indexmundi.com/commodities/?commodity=peanuts

According to the site's physical and economic data, TISD was run for all the former mentioned crop rotations under the line-source trickle irrigation system with the two configurations shown in (Khalifa 2020). Table 4 lists the summary of the model designs for the concerned field crops and their rotations. 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 4 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$/ha); annual labor cost (US$/ha); annual energy cost (US$/ha); annual maintenance cost (US$/ha); annual crop production cost (US$/ha).
3. The net cultivated area under line-source trickle irrigation system;
4. The expected annual net return per unit area of the farm, (US$/ha); and
5. The expected B/C ratio from the project.

Table 4: Design summary for field crops and their rotations in Egypt

Configuration no.	Fixed cost (US$/ha)	Total annual costs (US$/ha)							Net area (ha)	Net return (US$/ha)	B/C
		System	Land	Labor	Energy	Maintenance	Production	Total			
Sugar beet-soybean											
1	9870	1374	66	34	748	233	3014	5469	52.6	2068	1.38
2	11230	1451	66	34	702	240	2979	5472	52	1977	1.36
Lentil-soybean											
1	9870	1374	66	34	551	233	2413	4671	52.6	687	1.15
2	11230	1451	66	34	517	240	2385	4693	52	614	1.13
Chickpea-soybean											
1	9870	1374	66	34	560	233	1329	3596	52.6	803	1.22
2	11230	1451	66	34	526	240	1314	3631	52	759	1.21
Sugar beet-peanuts											
1	15574	1315	66	34	952	228	5737	8332	52.6	7884	1.95
2	14984	1279	66	34	949	224	5737	8290	52.6	7954	1.96
Lentil-peanuts											
1	16233	1315	66	34	732	228	5737	8112	52.6	6041	1.74
2	15618	1279	66	34	732	224	5737	8073	52.6	6114	1.76
Chickpea-peanuts											
1	12894	1315	66	34	743	228	4654	7040	52.6	6148	1.87
2	12405	1279	66	34	741	224	4654	6998	52.6	6148	1.88
Lupine-sesame											
1	4211	606	66	23	549	103	2197	3544	52.6	3941	2.11
2	5040	652	66	23	437	108	2180	3465	52.2	3958	2.14
Lentil-sesame											
1	4522	606	66	23	533	103	2631	3962	52.6	3588	1.91
2	5419	652	66	23	426	107	2611	3884	52.2	3608	1.93
Chickpea-sesame											
1	2592	606	66	23	549	103	1547	2894	52.6	2604	1.90
2	3102	652	66	23	437	107	1536	2820	52.2	2610	1.93
Sugar beet-sesame											
1	5280	606	66	23	743	103	3232	4773	52.6	5635	2.18
2	6320	652	66	23	593	107	3208	4648	52.2	5688	2.22
Garlic-soybean											
1	9870	374	66	34	624	233	4674	7006	52.6	3824	1.55
2	11230	1451	66	34	588	240	4621	7000	52	3709	1.53
Peas-soybean											
1	9870	1374	66	34	613	233	1527	3847	52.6	769	1.20
2	11230	1451	66	34	576	240	1510	3877	52	731	1.19
Cabbage-soybean											
1	9870	1374	66	34	613	233	3225	5545	52.6	3159	1.57
2	11230	1451	66	34	576	240	3188	5556	52	3062	1.55

Configuration no.	Fixed cost (US$/ha)	Total annual costs (US$/ha)							Net area (ha)	Net return (US$/ha)	B/C
		System	Land	Labor	Energy	Maintenance	Production	Total			
Garlic-peanuts											
1	9175	1315	66	34	814	228	7999	10456	52.6	10139	1.97
2	8493	1278	66	34	812	224	7999	10413	52.6	10203	1.98
Peas-peanuts											
1	9175	1315	66	34	803	228	4852	7298	52.6	5197	1.71
2	8493	1278	66	34	801	224	4852	7254	52.6	5245	1.72
Cabbage-peanuts											
1	9175	1315	66	34	803	228	6550	8996	52.6	9844	2.09
2	8493	1278	66	34	801	224	6550	8953	52.6	9907	2.11
Lupine-eggplant											
1	5450	658	66	19	380	107	4211	5442	51.7	5736	2.05
2	5498	663	66	19	366	107	4211	5433	51.7	5745	2.06
Lentil-eggplant											
1	5450	658	66	19	364	107	4638	5853	51.7	5293	1.90
2	5498	663	66	19	350	107	4638	5844	51.7	5300	1.91
Chickpea-eggplant											
1	5450	658	66	19	380	107	3573	4803	51.7	4748	1.99
2	5498	663	66	19	366	107	3573	4794	51.7	4755	1.99
Lupine-watermelon											
1	5450	658	66	19	396	107	4053	5299	51.7	6028	2.14
2	5498	663	66	19	382	107	4053	5290	51.7	6035	2.14
Lentil-cantaloupe											
1	5450	658	66	19	368	107	3396	4615	51.7	2437	1.53
2	5498	663	66	19	355	107	3396	4606	51.7	2440	1.53
Lentil-cowpea											
1	5450	658	66	19	323	107	3567	4740	51.7	3763	1.79
2	5498	663	66	19	311	107	3567	4733	51.7	3769	1.80
Chickpea-watermelon											
1	5450	658	66	19	396	107	3414	4661	51.7	4962	2.06
2	5498	663	66	19	382	107	3414	4652	51.7	4968	2.07
Chickpea-cantaloupe											
1	5450	658	66	19	384	107	2331	3566	51.7	1889	1.53
2	5498	663	66	19	371	107	2331	3557	51.7	1891	1.53
Sugar beet-cantaloupe											
1	4665	597	66	21	528	101	4071	5384	52.8	3452	1.64
2	4455	574	66	21	551	101	4071	5384	52.8	3453	1.64
Sugar beet-cowpea											
1	4665	597	66	21	487	101	4246	5518	52.8	5700	2.03
2	4455	574	66	21	508	101	4246	5515	52.8	5702	2.03
Garlic-sesame											
1	10872	1417	66	32	615	235	4829	7195	52	6079	1.85
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cabbage-sesame											
1	10872	1417	66	34	604	235	3398	5755	52	5202	1.90
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tomato-sesame											
1	10872	1417	66	40	689	235	5248	7696	52	10624	2.38
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Configuration no.	Fixed cost (US$/ha)	Total annual costs (US$/ha)							Net area (ha)	Net return (US$/ha)	B/C
		System	Land	Labor	Energy	Maintenance	Production	Total			
Onion-sesame											
1	10872	1417	66	38	654	235	5037	7448	52	3551	1.48
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Garlic-eggplant											
1	9433	1253	66	28	490	219	6928	8983	52.2	8102	1.90
2	9461	1255	66	28	405	219	6928	8901	52.2	8188	1.92
Garlic-watermelon											
1	7512	940	66	26	515	162	6767	8475	52.2	9030	2.07
2	7540	942	66	26	428	162	6767	8390	52.2	9109	2.09
Garlic-cantaloupe											
1	9433	1253	66	26	519	219	5673	7756	52.2	4534	1.58
2	9461	1255	66	26	430	219	5673	7669	52.2	4577	1.60
Garlic-cowpea											
1	7512	940	66	26	462	162	5846	7501	52.2	6850	1.91
2	7540	942	66	26	382	162	5846	7423	52.2	6926	1.93
Onion-eggplant											
1	9433	1253	66	32	533	219	7137	9240	52.2	5597	1.61
2	9461	1255	66	32	442	219	7137	9151	52.2	5697	1.62
Onion-cantaloupe											
1	9433	1253	66	30	563	219	5883	8013	52.2	3431	1.43
2	9461	1255	66	30	467	219	5883	7920	52.5	3479	1.44
Onion-cowpea											
1	7512	940	66	30	506	162	6055	7758	52.2	4588	1.59
2	7540	942	66	30	419	162	6055	7674	52.2	4675	1.61
Peas-sesame											
1	10872	1417	66	34	604	235	1723	4079	52	1771	1.43
2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Applying the trickle irrigation system with its configurations to the case study may attain the desired economic goal based on physical and economic parameters of costs and returns. For the trickle system configuration, the laterals' direction may be parallel to the farm width (configuration 1) or the farm length (configuration 2). It is shown from Table 4 that the net return and B/C ratio don't depend on the configuration type but can depend on the crop rotations as shown in Figure 2. In this figure, it is revealed that the very high amounts of net return of the rotations are garlic-peanuts, eggplant-peanuts, tomato-sesame, garlic-eggplant, and watermelon, respectively. This renders that the garlic, peanuts, eggplant, tomato, and watermelon are the highest average crop prices over the remaining crops. In addition, most B/C of crop rotations lie between 1.5 and 2.0 and some exceed 2.0 due to high net returns. Some rotations have got B/C in the range of 1.0~1.5. Such rotations are sugar beet-soybean, lentil-soybean, chickpea-soybean, peas-soybean, onion-sesame, onion-cantaloupe, and peas-cantaloupe. These rotations have got net returns ranges from less than 1000 US$/ha to nearly 2000 US$/ha. Some exceptions occurred such as onion-sesame and onion-cantaloupe referring to high total costs for both rotations. From the previous analysis, it showed that investment in crops using a trickle irrigation system was economically viable. Furthermore, higher ratios of B/C of crop rotations indicated that more investment should be encouraged.

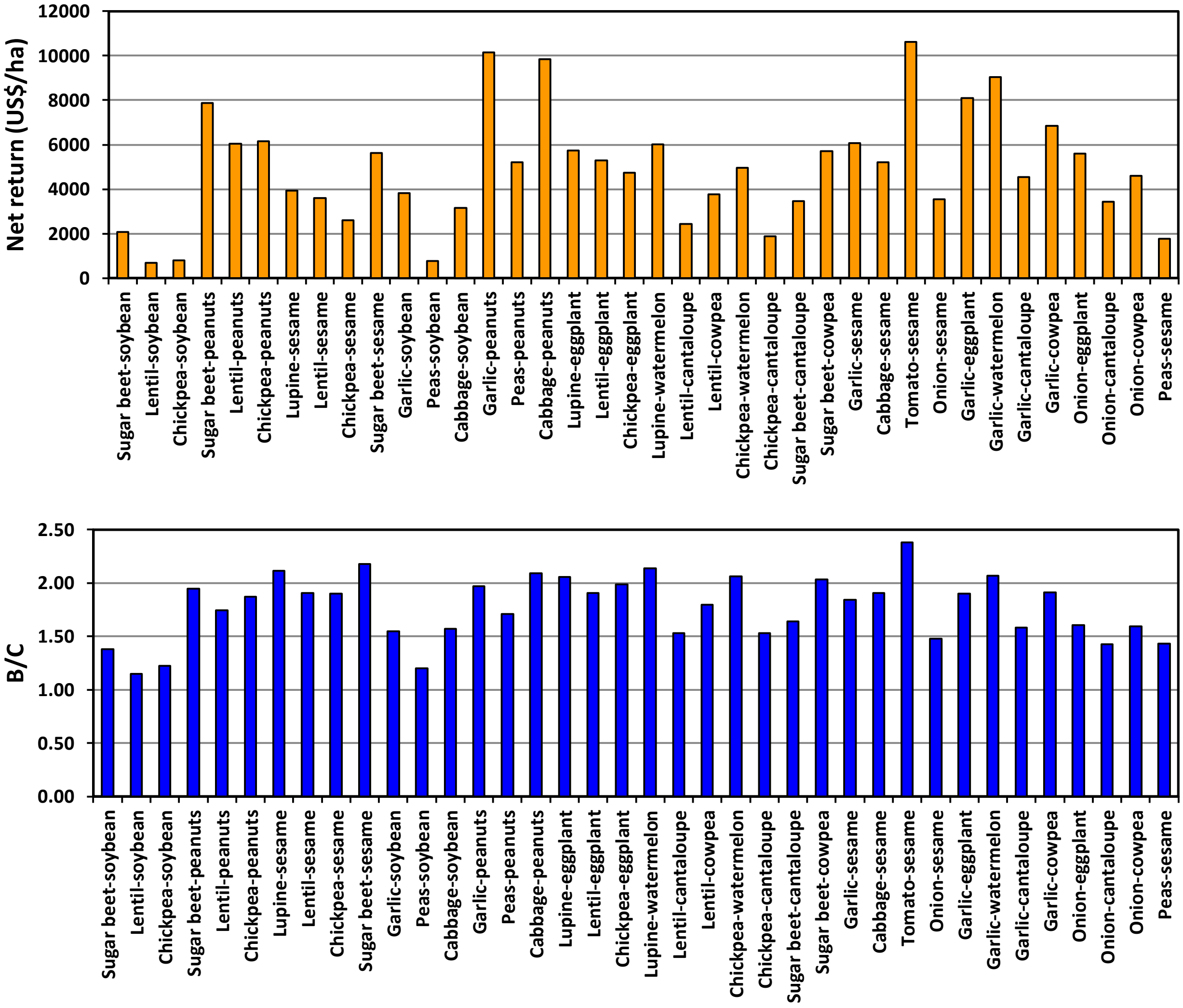

Figure 2: Comparison of the amount of return for the field crop rotations in Egypt (2018)

4. CONCLUSION

Arab countries such as Egypt are water-scarce countries, and their agriculture sectors require irrigation water to feed the hastily rising population. For developing countries, agricultural water demands are estimated to escalate more than before. Therefore, a shift to water-saving technologies such as a trickle irrigation system is necessary to keep using the balance of this valuable resource under competitive uses. This study was designed to analyze the economic perspective of growing crops and vegetables in a hypothetical field in Egypt based on the physical and economic conditions using the developed model of trickle irrigation system design (TISD). The economic analysis measures in the study used the net return values $(\mathrm{B}-\mathrm{C})$ and benefit-cost ratio (B/C). The crops and vegetables considered in the study were sugar beet, lupine, lentil, chickpea, soybean, sesame, peanuts, tomato, onion, garlic, peas, cabbage, eggplant, watermelon, cantaloupe, and cowpea, respectively. The study presented some suitable growing rotations among the crops and vegetables. From this study's findings, it was concluded 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. The higher values of net returns and the B/C ratio indicated better economic viability of the trickle irrigation system in the study area.

5. AVAILABILITY OF DATA AND MATERIAL

All relevant data are already included in this article.

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