Chapter V

Results and Discussion

This chapter is devoted for results of the study and explanation of the results. At the beginning of the chapter, detail on banana cultivation are discussed including banana cultivation land size, water use for banana cultivation, cost of production and income of the banana cultivation .Secondly, results of the descriptive statistical test and changing trend of observable sustainability indicator are elaborate under socio economic, agronomic and ecological criteria. Then the result that obtained from stakeholder workshops is presented. At the end, results of the overall sustainability index for two systems are presented.

5.1 Banana cultivation

5.1.1 Banana cultivated area in sample households

Most of the farmers who were in the sample are smallholder. Maximum banana cultivate land extent is 8,000 m^2. Minimum banana cultivated land size is 1,000 $m^{2.}$ Majority of the farmers cultivate banana 2,000 m^2 land using shallow well water. It is about 63 percentages of total samples. From total sample, about 23 percent of farmers cultivate 3,000 m^2 of land size (see Table 5.1).

Table 5.1 Banana cultivated land extent in the sample

Land extend (M^2)	**Number of farmers**	**Farmer percentage**
1,000	2	1.96
1,500	1	0.98
2,000	64	62.75
3,000	23	22.55
4,000	8	7.84
6,000	3	2.94
8,000	1	0.98
Total	102	100.00

Source: Computed from field survey during 2006

When consider irrigation methods and cultivated land extent, about 69 percent of farmers in drip irrigated banana system cultivate 2,000 m^2 plots and in surface irrigated banana, 57 percent of farmers use 2,000 m^2 plot sizes to cultivate banana. Maximum land size in drip irrigated banana is 3,000 m^2. But some farmers those who use surface irrigation, cultivate banana 8,000 m^2 plots. However, greater part of the farmers in both systems use 2,000 m^2 land plots to cultivate banana, using ground water (Table 5.2).

When consider cultivation land size, majority of the farmers in the two systems use small land size. The reasons of selecting small land size in drip irrigation system are deferent with reasons of selecting small land size in surface irrigation system. Farmers those who use drip irrigation, should invest large amount of capital investment to start the cultivation. It is around 180,000 rupees per hectare and lack of initial capital confined land size in small. However, in case of the surface irrigation system, most of the farmers cannot expand their land due to limitation of water in their wells. During the peak drought, considerable numbers of farmers suffer lack of water to manage their existing cultivation.

Table 5.2 Comparison of cultivated land size (m^2) percentages in two systems

Land extent (m^2)	**Surface irrigated banana**		**Drip irrigated banana**	
	Number of farmers	Farmer percentage	Number of farmers	Farmer percentage
1,000	2	3.70	-	-
1,500	-	0.00	1	2.08
2,000	31	57.41	33	68.75
3,000	11	20.37	12	25.00
4,000	6	11.11	2	4.17
6,000	3	5.56	-	-
8,000	1	1.85	-	-
Total	54	100.00	48	100.00

Source: Computed from field survey during 2006

5.1.2 Annual water pumped for banana cultivation

Using existing information in the survey field and farmers experience, annual water pumped from wells to banana cultivation plots was estimated. Pump capacity and emitter discharge rate were consider as existing information. Irrigation interval and irrigation duration per one time were realized from farmers experience to estimate amount of water per hectare per year.

In surface irrigated banana system, maximum value for annual water pumped is 18,144 cubic meter per hectare and minimum is 720 cubic meter per hectare

Nevertheless, drip irrigated banana reported annual maximum water pumped is 6,816 cubic meters per hectare in the sample. Minimum water pumped for drip irrigated land is 1,400 cubic meters per hectare.

Eventually, average amount of water pumped for surface irrigated banana is 2.5 fold higher than drip irrigated banana cultivation. Annual average amount of water pumped for surface irrigated banana land is 7,957 cubic meters per hectare and 3,130 cubic meters per hectare for drip irrigated cultivation. These averages are significant difference at one percent level (Table 5.3).

Table 5.3 Annual water pumped to unit banana land in two systems

	Surface irrigated banana (m^3 per ha)	**Drip irrigated banana** (m^3 per ha)
Maximum	18,144.00	6,816.00
Minimum	720.00	1,400.00
Mean***	7,957.00	3,130.00
Standard deviation	3,657.00	1,061.00
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.1.3 Production cost of banana cultivation

The variable cost which spent during year 2005 and fixed cost (depreciation for farm structure, equipment and machinery) year 2005 are included in total cost of production. Even though, some farmers in drip irrigated banana cultivation obtained subsidies to buying drip irrigation equipments, when depreciate the drip equipments, real prices were considered.

Annual production cost of banana under surface irrigation system is higher than cost of production in drip irrigated system. When consider maximum cost of production in surface irrigated banana it is about 330,654 rupees per hectare. In case of drip irrigated banana, it is about 232,778 rupees per hectare. Minimum annual

production cost of surface irrigated banana and drip irrigated banana are 82,041 and 111,529 rupees per hectare respectively.

Average annual production cost of surface irrigated banana is higher than cost of production with drip irrigation. Average annual cost for surface irrigated banana. The study considers cost of banana production during year 2005. Age of the all cultivation is higher than four years. Therefore, initial investment for both system were not considered when calculate. The average cost for drip irrigated banana land is 219,402 rupees per hectare and drip irrigated banana is 167,258 rupees per hectare. Theses means are statistically significant difference at one percent level (see Table 5.4).

Table 5.4 Production cost of banana under two irrigation methods

	Surface irrigation (Rs/ha)	**Drip irrigation** (Rs/ha)
Maximum	330,654	232,778
Minimum	82,041	111,529
Mean ***	219,402	167,258
Standard deviation	61,333	25,178
Number of observation	54	48

Note: *** indicate that means are significant difference at 1 % level using t-test with unequal variances

Source: Computed from field during survey 2006

Contributions of cost items for the average cost are different with two systems. Labor cost (excluding labor for irrigation) in surface irrigation system demonstrates 33 percent while the drip irrigated banana show 26 percent of labor cost. Fertilizer cost show 28 percent and 20 percent in surface irrigated banana and drip irrigated banana respectively.

Variable cost for Irrigation (Energy cost + Labor for irrigation) in surface irrigated banana is 24 percent when consider total average cost for surface irrigated

banana, but in drip irrigated banana show 19 percent as their variable irrigation cost. When consider transport cost of two systems, drip irrigated banana farmers allocate 11 percent from annual average cost for transport and surface irrigated banana farmers use eight percent from their average annual cost for transport.

When consider total depreciations in two systems, surface irrigated banana cultivations show about two percent of depreciation from total annual cost but drip irrigated banana cultivation show about 13 percent of depreciation cost from total annual cost. From theses percentages, about12 percent of depreciation in drip irrigated banana obtained from depreciation of irrigation items other one percent from non irrigation items. In case of surface irrigation, about one percent of depreciation cost coming from irrigation items and less than one percent coming from non-irrigation items (see Table 5.5).

Table 5.5 Contribution of cost items for annual average cost in two systems

	Surface irrigation		**Drip irrigation**	
	Cost (Rs/ha)	%	Cost (Rs/ha)	%
Variable cost				
Labor	72,402.86	33.00	44,375.87	26.70
Irrigation	52,656.08	24.00	32,130.00	19.40
Fertilizer	61,431.00	28.00	33,671.00	20.26
Transport	17,652.00	8.04	18,340.00	11.03
Prop	4,390.00	2.00	7,622.11	4.60
Other	6,679.05	3.04	9,232.00	5.55
Fixed cost				
Depreciation				
Irrigation items	3,250.00	1.49	19,575.00	11.71
Non irrigation	942.00	0.43	1,250.00	0.75
Total	219,402.99	100.00	167,258.98	100.00

Source: Computed from field during survey 2006

Although, surface irrigated banana show higher labor cost than drip irrigated banana, composition of labor cost item is different within two irrigation methods. Grater part of labor cost expend for weeding in surface irrigated banana it is about 39 percent from total average labor cost. However, in case of the drip irrigated banana spend significant part of labor cost for harvesting, it is about 42 percent of average labor cost of drip irrigated banana cultivation. While surface irrigation banana growers use 23 percent on harvesting, drip irrigation field use 15 percent of labor for weeding.

When drip irrigation farmers expend about 29 percent of labor for bush management, surface irrigation farmers use only 24 percent of average labor cost (Table 5.6).

Table 5.6 Comparison of labor cost items in two systems

Cost items	Surface irrigation		Drip irrigation	
	Cost(Rs/ha)	%	Cost(Rs/ha)	%
Harvesting	16,610.15	23.94	18,540.13	41.78
Bush clearing	17,353.27	23.96	12,845.21	28.94
Weeding	28,295.00	39.10	6,757.25	15.23
Prop supply	6,519.17	9.00	4,882.17	11.00
Other	3,625.27	5.00	1,351.11	3.05
Total labor cost	**72,402.86**	100.00	**44,375.87**	100.00

Source: Computed from field during survey 2006

If consider total irrigation cost in two systems, contribution of items for total irrigation cost are different. In surface irrigated banana, 39 percent from total irrigation cost contribute for labor cost for irrigation activities and 54 percent for energy. Fixed cost for irrigation for surface irrigation, only five percent is contribute to total irrigation cost. In case of drip irrigation, labor costs for irrigation contribute 13 percent of total irrigation cost and 49 percent for energy. However, fixed cost for irrigation in drip irrigated banana is somewhat higher value when compare with surface irrigated banana. It is about 37 percent of total irrigation cost (see Table 5.7).

When consider cost of cultivation in two systems surface irrigated banana has higher cost due to many reasons. Firstly, farmers who use surface irrigation, use more labor for irrigation activity. Secondly, weeding increase labor requirement in surface irrigated banana it affect on cost of cultivation of banana in surface irrigation systems. Thirdly, fertilizer cost play major role in cost of production in surface irrigated banana. Finally, farmers in surface irrigated banana lands pump more water form wells to banana fields and it will increase energy cost.

Table 5.7 Composition of total irrigation cost in two systems

Cost item	Surface irrigation		Drip irrigation	
	Cost (Rs/ha)	%	Cost (Rs/ha)	%
Variable cost				
Labor for irrigation	22,115.13	39.56	6,748.25	13.05
Energy	30,541.17	54.63	25,382.32	49.09
Fixed cost				
Depreciation value of irrigation items	3,250.32	5.81	19,575.20	37.86
Total	55,906.62	100.00	51,705.75	100.0

Source: Computed from field during survey 2006

5.1.4. Income of banana cultivation

There are two sources for income in banana cultivation. Main income source is banana bunch. Other one is banana plants as planting material for new cultivation. Maximum annual income of surface irrigated banana farmers is 700,300 rupees per hectare in the sample and minimum income is 100,850 rupees per hectare. Maximum annual income from drip irrigated fields is 1,384,350 rupees per hectare and minimum income is 285,035 rupees per hectare. While average annual income for drip irrigation is 762,261 Rupees per hectare, surface irrigated banana cultivation give 398,822 rupees per hectare as average annual income. These means are significant difference at one percent level. Income from planting materials in both systems is not significant at five percent level. Therefore, the difference of total income in two systems due to income from banana bunches. Statistical test realized income from banana bunches are significant difference at one percent level (Table 5.8).

Table 5.8 Annual income of unit banana land in two systems

	Surface irrigated banana (Rs/ha)			Drip irrigated banana (Rs/ha)		
	Total income	**Banana bunch**	**Planting material**	**Total income**	**Banana bunch**	**Planting material**
Maximum	700,300	6,442,276	56,024	1,384,350	1,218,222	166,122
Minimum	100,850	10,850	0	285,035	285,035	0
Mean	398,822***	392,840***	5,982^{NS}	762,261***	755928***	6,333^{NS}
Standard deviation	160,392	152,987	2,405	229,322	19,840	21,003
Number of observations	54			48		

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances for corresponding components

^{NS} indicates that means are not significant difference at 5% level using t-test with unequal variances for corresponding components

Source: Computed from field survey during 2006

Income from the unit banana land under drip irrigation and surface irrigation show much difference. Low income form surface irrigated banana due to various causes. However, surface irrigated lands are used higher amount water; their irrigation interval is very longer than drip irrigated banana lands. They use 15 days to 20 days irrigation interval. Literature says if soil moisture goes below less than 33 % of field capacity, it greatly effects on the yield (Doorenbos *et al.,* 1986). Due to long irrigation interval surface irrigated banana cultivation face soil moisture stress, consequently yield may decrease. Other point is without sufficient soil moisture fertilizer uptaking efficiency is reduced. As the result of poor uptaking of fertilizer, yield cannot performance well. Even though, surface irrigated banana lands are used high amount

of chemical fertilizer, these lands do not show good yield than drip irrigated banana. Because these lands are used higher amount of fertilizer and higher amount of water in the same time. Excess amount of water will cause to fertilizer leaching down from root zone of banana plants. This phenomenon also may cause to yield reduction of the surface irrigated banana fields

5.2 Level of Sustainability indicators in banana cultivation

When independently consider magnitudes of selected nine indicators under socioeconomic, ecological, and agronomic criteria in two systems, give partial idea on sustainability in different discipline of the systems

5.2.1 Socioeconomic sustainability indicators

These indicators reflect economic conditions and social life of the banana grower in Anuradhapura district under drip irrigation and surface irrigation. At the same time it gives some idea, how these indicators contribute to overall sustainability of the systems.

5.2.1.1 Annual net profit per unit banana land (NP)

Although, cost of cultivation is not very much different in two systems, farmers who use drip irrigation, enjoy higher profit than surface irrigated banana because of higher income.

In case of surface irrigated banana, show 477,958 rupees per hectare and 5,285 rupees hectare as their maximum and minimum profits respectively. Maximum profit that reported by drip irrigated banana farmers is 1,196,066 per hectare and minimum profit is 136,182. At the same time, average of the annual profit for drip irrigated banana fields is three fold larger than surface irrigated banana cultivation. While drip irrigated banana lands report average annual profit is 595,003 rupees hectare, surface irrigated cultivation show only 179,420 rupees per hectare, and statistical test say mean of annual profit of the two systems is significant difference at one percent level

(Table 5.9). This indicator reflect drip irrigated banana has higher socio economic sustainability than surface irrigated banana cultivation.

Net profits of the banana cultivation under two irrigation methods are significant. Surface irrigated banana cultivation obtained low profit due to low income and higher management cost.

Table 5.9 Results of the independent two sample t-test for annual net profit for banana cultivation

	Surface irrigated banana (Rs per ha)	**Drip irrigated banana** (Rs per ha)
Maximum	477,958	1,196,066
Minimum	5,285	136,182
Mean***	179,420	595,003
Standard deviation	141,222	224,613
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Normalized values for net profit

Majority of the surface irrigated farmers have lower normalized values for annual net profits it is about 70 percent (38 farmers out of 54) of the total surface irrigated banana growers. Other 30 percent of surface irrigated farmers show normalized values for annual net profits in between 0.21 to 0.40.

In case of the drip irrigated banana cultivation, their normalized values for net profit cover from 0.00 to 1.00. Nevertheless, these values condense between 0. 21 to 0.80 range. Large numbers of farmers are in 0.41 to 0.60 indicator range. It is 17 farmers, 35 percent of total drip irrigated farmers, and another 31 percent of farmers

are in 0.21 to 0.40 range. However, average normalized value of net profit for drip irrigation is 3.6 times higher than surface irrigated land and statistically these averages are significant at one percent level (Table 5.10).

Table 5.10 Farmers frequency of normalized net profit and average normalized net profit in two systems

Normalized indicator range	Surface irrigated banana		Drip irrigated banana	
	Number of farmers	%	Number of farmers	%
0.0 to 0.20	38	70.37	2	4.17
0.21 to 0.40	16	29.63	15	31.25
0.41 to 0.60	-	-	17	35.41
0.61 to 0.80	-	-	12	25.00
0.81 to 1.00	-	-	2	4.17
Total	54	100.00	48	100.00
Average normalized value ***	**0.15**		**0.50**	

Note: ** * indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.2.1.2 Water productivity of banana cultivation (WP)

Water productivity of banana cultivation implies efficiency usage of ground water with respect to production. There are two components that responsible for water productivity of banana; amount of water used per unit banana land and amount of income earned form unit banana lands. Drip irrigated banana cultivations are used less water than surface irrigated banana and produce more income than surface irrigated banana (see Table 5.3 and 5.8). Because of these causes, water productivity

of the drip irrigated banana land is considerably higher than surface irrigated banana lands. Among the drip irrigated banana growers, 634 rupees per cubic meters reported as their maximum water productivity. However, surface irrigated farmers demonstrate 181 rupees per cubic meter as their maximum value. When drip irrigated banana repot 106 rupees per cubic meter as minimum water productivity for their lands, surface irrigated lands show 13 rupees per cubic meter as minimum water productivity.

However, average annual water productivity of drip irrigated banana lands is 259 rupees per cubic meter of water and for surface irrigated banana; it is 56 rupees per cubic meter of water. Annual average water productivity of drip irrigated banana is four times higher than surface irrigated banana lands and statistically it is significantly difference at one percent level (Table 5.11). This indicator give facts, drip irrigated banana cultivation has higher socio economic sustainability than surface irrigated banana cultivation.

Table 5.11 Results of the independent two sample t-test for water productivity of two systems

	Surface irrigated banana (Rs per m^3)	**Drip irrigated banana** (Rs per m^3)
Maximum	181.00	634.00
Minimum	13.00	106.00
Mean***	55.00	258.00
Standard deviation	55.00	33.00
Number of observations	54.00	48.00

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Drip irrigated banana lands demonstrate significantly higher water productivity due to higher amount of annual income and lower amount of water use. Nevertheless, in surface irrigated banana lands using higher amount of water produce

comparatively lower income. Therefore surface irrigated land show low level of water productivity.

Normalized values for water productivity

When compare two systems using normalized value of water productivity, majority of the surface irrigated banana farmers obtained lower normalized values. Forty seven farmers from surface irrigated banana obtained normalized value in 0.00 to 0.20 range; it is 87 percent of total surface irrigated farmers. Other 13 percent of farmers show normalized water productivity between 0.21 to 0.40 range. But in case of the drip irrigation, 23 of farmers show 0.41 to 0.60 range. It is 48 percent of the total drip irrigated banana farmers. No one got Normalized water productivity in drip irrigated banana cultivation between 0.00 to 0.20, but 10 farmers (21%) got normalized water productivity values between 0.21 to 0.40 and 10 farmers (21%) got 0.41 to 0.60 range. Only five farmers (10%) show normalized water productivity above 0.81. When consider normalized average value of water productivity for two systems, drip irrigated system has more than three time higher normalized average values when compare the surface irrigated lands. These average values are significant difference at one percent level (Table 5.12).

Table 5.12 Farmers frequency of normalized water productivity and average normalized value for water productivity in two systems

Normalized indicator range	Surface irrigated banana		Drip irrigated banana	
	Number of farmers	%	Number of farmers	%
0.0 to 0.20	47	87.04	-	-
0.21 to 0.40	7	12.96	10	20.83
0.41 to 0.60	-	-	23	47.92
0.61 to 0.80	-	-	10	20.83
0.81 to 1.00	-	-	5	10.42
Total	54	100.00	48	100.00
Average normalized value ***	**0.17**		**0.55**	

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.2.1.3 Income variation of banana cultivations (IV)

The study has used income variation as socio economic indicator. In that case the coefficient of variation from monthly banana income is higher, it is implied income variation of banana cultivation is higher. If CV has lower value it is implied, monthly income variation through out the year is lower or income is stable though out the year.

Among the surface irrigated banana farmers minimum CV is 0.35 and their maximum CV is 1.00. In case of drip irrigated banana farmers, reported 0.06 as their minimum and 0.61 as maximum CV values.

Average CV value for drip irrigated grower is 0.19 and for surface irrigated banana filed it is reported 0.79. It dose mean that drip irrigated banana cultivation has more income stability than surface irrigated banana cultivation and statistically realized these average CV values are significant difference at one percent level (Table 5.13). This low value of CV in drip irrigated banana cultivation reflects higher socio economic sustainability than surface irrigated banana cultivation.

Reasons for that difference are, during the rainy season no soil moisture stress for banana under both systems that there is enough rainfall. When a drought is coming ground water level go down. If there is not enough water in the agro well, farmers tend to extend irrigation intervals. Twenty eight percent of farmers under surface irrigation reported they face water limitation during peak drought period (July to October). In drip irrigated banana cultivation, no one has this experience.

Farmers those who use drip irrigation, maintain irrigation interval one day to three days. Most of the farmers supply water in daily bases. However, some farmers use two days or three days.

In case of surface irrigated banana, irrigation intervals are spread from seven day to 20 days. Majority of the surface irrigation farmers use 11 days to 20 days irrigation intervals at peak drought. On the other hand, at normal dry months, they use short irrigation interval and when water is limit they use long interval. Insufficient soil moisture badly affect on nutrient adsorption. As the results of all factors yield is reduce drought and after drought in surface irrigated banana cultivation. Eventually, income stability of cultivation may reduce.

Table 5.13 Results of the independent two sample t-test for coefficient of variance of income

	Surface irrigated banana	**Drip irrigated banana**
Maximum	1.00	0.61
Minimum	0.35	0.60
Mean***	0.79	0.19
Standard deviation	0.15	0.11
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Normalized values for income variation

Raw values for income variation and normalized values for the income variation give opposite meaning. If a raw value of income variation is higher it means income fluctuation is higher. But normalized value for income variation is higher it imply income fluctuation is lower. In term of sustainability, higher value (close to the one) is better. In the surface irrigated banana cultivation, majority of the (52%) are in zero to 0.20 normalized indicator range. Larger part of the farmers condenses in zero to 0.04 normalized indicator ranges and no farmers in 0.81 to 1.00 range.

Greater part of the drip irrigated banana farmers show higher level of normalized value for income variation. 42 farmers out of 48, show normalized income variation in between 0.81 to 1.00 range. No farmers in 0.0 to 0.60 range.

When compare normalized average value for income variation of two systems, drip irrigated banana land has more than three time value than surface irrigated banana lands (Table 5.14) and normalized average values of income variation is significant different at one percent level.

Table 5.14 Farmers frequency of normalized income variation and normalized average values of income variation in two systems

Normalized indicator range	Surface irrigated banana		Drip irrigated banana	
	Number of farmers	%	Number of farmers	%
0.0 to 0.20	28	51.85	-	-
0.21 to 0.40	20	37.04	-	-
0.41 to 0.60	5	9.26	3	6.25
0.61 to 0.80	1	1.85	3	6.25
0.81 to 1.00	-	-	42	87.50
Total	54	100.00	48	100.00
Normalized average value* **	**0.22**		**0.86**	

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.2.1.4 Farmer social participation (SOP)

Individual farmers social participation has used as socio economic indicator in the study. When compare the two systems, farmers who use surface irrigation to grow banana show 100 percent and zero percent for their maximum and minimum social participation rate respectively. In drip irrigated banana show 100 percent as their maximum social participation and 41 percent of their minimum social participation.

However, farmers who use drip irrigation demonstrated slightly high percentage for social participation than surface irrigated farmers; statistical test show averages of social participation of two systems are not significant at five percent level. Average social participation for drip irrigated farmers is 86 percentages and for surface irrigated farmers is 79 percentages in the samples (Table 5.15).

Table 5.15 Results of the independent two sample t-test for social participation rate

	Surface irrigated banana	**Drip irrigated banana**
	%	**%**
Maximum	100.00	100.00
Minimum	0.00	41.00
Mean [NS]	79.00	86.00
Standard deviation	19.00	13.00
Number of observations	54	48

Note: [NS] indicates that means are not significant difference at 5% level using t-test with unequal variances

Source: Computed from field survey during 2006

Even though, farmer who use drip irrigation to cultivate banana utilize less labor for irrigation activity then surface irrigated banana lands, social participation of the farmers in both system are not significant difference. Probably, farmers in the two systems are paying equal attention on social participation. Therefore, two systems did not show significant difference on social participation

Normalized values for farmer social participation

Farmers who use surface irrigation, normalized values for social participation spread out 0.00 to 1.00. However, no farmers in 0.21 to 0.40 range. Majority of the farmers obtained normalized average values for social participation in 0.81 to 1.00 range. It is 32 farmers out of 54 and 59 percent of total surface irrigated banana grower. Eighteen farmers in surface irrigated system show their normalized values for social participation in between 0.61 to 0.80. All farmers in drip irrigated banana system obtained normalized farmer social participation values above 0.41. Majority of the farmers (36 farmers out of 48) in drip irrigated system show their normalized value for social participation in between 0.81 to one range it is 75 percent of total drip

irrigated cultivations. Nineteen percent of dip irrigated grower obtained their normalized values in between 0.61 to 0.80 range and other six percent show 0.41 to 0.60 range

When compare normalized values of the farmer social participation of two systems, values are not much difference in two systems. While drip irrigated system show, 0.86 as their normalized average value for social participation surface irrigation reported 0.79 as their average value and these values are not significant difference at five percent level (Table 5.16).

Table 5.16 Farmers frequency of normalized farmer social participation and average normalized values in two systems

Normalized indicator range	**Surface irrigated banana**		**Drip irrigated banana**	
	Number of farmers	%	**Number of farmers**	%
0.0 to 0.20	2	3.70	-	-
0.21 to 0.40	0	0.00	-	-
0.41 to 0.60	2	3.70	3	6.25
0.61 to 0.80	18	33.34	9	18.75
0.81 to 1.00	32	59.26	36	75.00
Total	54	100.00	48	100.00
Normalized average value [NS]	**0.79**		**0.86**	

Note: [NS] indicates that means are not significant difference at 5% level using t-test with equal variances

Source: Computed from field survey during 2006

5.2.2 Ecological sustainability indicators

These indicators provide idea how banana cultivation create ecological impact under two irrigation methods in study area.

5.2.2.1 Annual chemical fertilizer usage (CFU)

In order to get good performance of banana cultivation, chemical fertilizer has been recommended by department of agriculture. To convenience of farmers, recommendation has been given in fertilizer name. As said by recommendation using of 120 gram of Urea, 250 gram of Miuriate of Potash (MOP) and 80 gram of Triple Super Phosphate (TSP) per bush (with 3 plants) per one time is advisable. Fertilizer application frequency is three time per year. Based on this information, fertilizer recommendation for one hectare of banana is shown in the Table 5.17.

Table 5.17 Fertilizer recommendation for Banana cultivation

Name of the fertilizer	Recommended rate (Kg/ ha)
Urea	339
MOP	831
TSP	267

Source: DOA, 1995

This is a blanket recommendation for dry zone and intermediate zone banana cultivation. However, farmers use different amount of fertilizer in the field. In term of ecological sustainability, usage of low amount of inorganic fertilizer is better.

Urea utilization in the banana cultivation

Nitrate is one of most critical cation on ecology that release by the inorganic fertilizer. Urea gives nitrate in to the soil. It has less ability to retain soil. Excess parts of nitrate are leached in to the soil and mix with the ground water. This phenomenon depend on the two factors; NO_3 level in soil solution have to be significantly high and

down word movement of water has to be enough to displace the available NO_3 in to ground water. The first criterion is fulfilling most of the agricultural soil and second condition is frequently fulfilling by rain or excess amount of irrigation water (Ritter and Bergetrom, 2001).

Surface irrigated banana land are applied more urea than drip irrigated banana lands. Among the surface irrigated farmers, annual maximum use of urea is 1,500 kilogram per hectare and minimum amount is 211 kilogram per hectare. However, in drip irrigated banana land are used 750 and 66 kilogram per hectare as maximum and minimum amounts respectively. In fact, annual average amount of urea fertilizer usage of surface irrigated banana lands is more than double when compare the drip irrigated lands and these mean are significant difference at one percent level (Table 5.18).

Table 5.18 Amount of urea use in two systems

	Surface irrigated banana (Kg/ha)	**Drip irrigated banana** (Kg/ha)
Maximum	1500.00	750.00
Minimum	211.00	66.00
Mean***	834.00	362.00
Standard deviation	315.00	138.00
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Muriate of potash (MOP) utilization in the banana cultivation

MOP is available fertilizer for supply potassium in to banana cultivation in the district. MOP contains 40 % of KO_2 to provide K^+ in to soil. Soil colloids can easily bound with K^+ in the soil solution. Therefore leaching and wash away form

root zone is less chance than nitrate. Behera (2003) realized the mobility of K^+ was found to be lower than that of $NO3^-$. However, excess amount of K^+ has risk pollution of ground water and soil.

Among the surface irrigated farmers, maximum utilization amount of MOP is 1,625 kilogram per hectare. But MOP is not used some farmers in this system. All farmers who use drip irrigation apply MOP in to their banana lands. The field survey show, drip irrigation lands are used 1,075 kilogram per hectare as their maximum amount and 320 kilogram per hectare as their minimum amount.

Average utilization of MOP among surface irrigated lands is approximately two times than drip irrigated lands. While average amount in surface irrigated banana lands is 989 kilogram per hectare, 550 kilogram use in drip irrigated lands as their average amount of MOP and these averages are significant difference at one percent level (Table 5.19).

Table 5.19 Amount of MOP use in the two systems

	Surface irrigated banana (Kg/ha)	**Drip irrigated banana** (Kg/ha)
Maximum	1625.00	1075.00
Minimum	0.00	320.00
Mean***	989.00	550.00
Standard deviation	346.00	177.00
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Triple super phosphate (TSP) utilization in banana cultivation

Unlike nitrate and potash fertilizer, TSP less soluble and leaching ability is lower than other two fertilizers unless conditions for leaching are preverbal, like sandy soils, organic soil , high soil Phosphate contain and low soil Aluminum and

ferrous contain. Mostly excess Phosphate may be subjected to runoff and it will contribute pollution of surface water bodies (Campbell and Dwayne, 2001).

When compare two systems of banana cultivation, surface irrigated lands are used somewhat higher amount of the TSP. Maximum amount of TSP is reported among surface irrigated land is 1,625 kilogram per hectare. But some farmers do not use TSP at all. Drip irrigation with banana lands are used 875 kilogram per hectare as maximum amount. Minimum amount that use in drip irrigated lands is 50 kilograms. Annual average amount of TSP use in drip irrigated lands is 373 kilograms per hectare and surface irrigated land is 546 kilograms per hectare. These average values are significant difference at one percent level (see Table 5.20).

Table 5.20 Amount of TSP utilization in two systems

	Surface irrigated banana (Kg/ha)	**Drip irrigated banana** (Kg/ha)
Maximum	1625.00	875.00
Minimum	0.00	50.00
Mean***	546.00	373.00
Standard deviation	306.00	165.00
Number of observations	54	48

Note: *** indicates that means are significant difference at 1 % level using t-test with unequal variances

Source: Computed from field survey during 2006

Fertilizer application methods

Usually, fertilizer is applied by manually. There are some conditions, which fulfill to obtain good performance from fertilizer application. One of important factor is sufficient soil moisture in the soil at fertilizer application time. If soil moisture is not sufficient in root zone of banana plant, fertilizer up taking efficiency will be gown down. On the other hand, excess water will leach out or wash away fertilizer from

root zone. It is also affected on plant uptake. Excess amount of fertilizer in soil will enhance leaching to ground water and contaminate runoff water.

In drip irrigation practice, farmers use fertigation other than annual applying of fertilizer. Some farmers apply urea and MOP fertilizer through drip irrigation systems by using fertigation units. Sixty percentage of farmers in drip irrigated banana use fertigation to supply N and K nutrients to cultivations and other practice usual manual method. However, TSP is applied only by manually.

Farmers who use surface irrigation practice manual method to supply all kind of fertilizer (Table 5.21).

Table 5.21 Farmers percentages of fertilizer application method in two systems

Type of Fertilizer	Surface irrigation		Drip irrigation	
	Farmer Percentage		Farmer Percentage	
	Manual	Fertigation	Manual	Fertigation
Urea	100.00	-	40.00	60.00
MOP	100.00	-	40.00	60.00
TSP	100.00	-	100.00	-

Source: Computed from field survey during 2006

When use fertigation, very little amount of fertilizer apply within one time. However, frequency of application is considerably higher than manual method. Fertigation cut down labor requirement for fertilization. Limitation of fertigation is all fertilizer must be highly soluble in water. Farmers grow banana with drip irrigation, use urea, MOP, and TSP to supply nutrients for their cultivation. Solubility of TSP fertilizer is very low. Therefore, farmers, who use fertigation, apply TSP manually.

When consider three types of fertilizer usage in two systems and recommendation amount of three fertilizers for one year, average of all kind of fertilizer are used more than recommended amount in surface irrigated banana

cultivation. Fertilizer Recommendations for one year is urea. MOP and TSP are 339 kg, 831 kg and 267 kg respectively. However, in surface irrigated system used 831 kg of urea, 989 kg of MOP and 546 kg of TSP for their cultivation during one year period. In case of drip irrigated banana used less amount of MOP for their cultivation. Nevertheless, other two type of fertilizer used more than recommended amount. In drip irrigated banana, 362 kg of urea, and 550 kg of MOP and 337 kg of TSP used as their annual average fertilizer. Recommendation amount and used amount of three kind of fertilizer in two systems are represented in Figure 5.1.

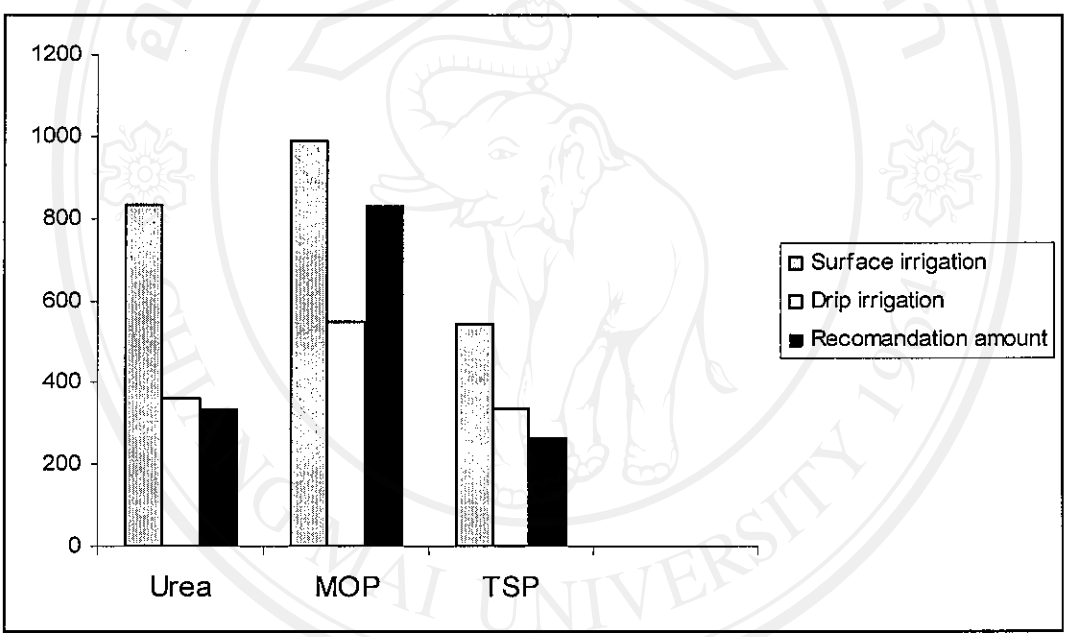

Figure 5.1 Average fertilizer used in the banana cultivation and recommended amount

Source: Computed from field survey during 2006

Total fertilizer usage

Even though, there is a Fertilizer recommendation for banana, different individual in sample used different type of combinations of the three fertilizers. Some use all fertilizer, some use only one type some use two type of fertilizer. If directly sum up total amount that individual farmer used. It will not reflect importance of each type of fertilizer. Therefore, before add all three kind of fertilizer to get total amount of fertilizer at household level, the amount of fertilizer that used in each individual

farmer are divided by using recommended amount of each fertilizer and got relative proportion of recommended amount of urea, MOP, and TSP. After that this figures were added together and got indicator value for total fertilizer usage at household level. When compare this indicator values in two systems in surface irrigate banana lands demonstrate 10.69 as their maximum value and drip irrigated lands show 6.69 as their maximum value. While surface irrigated land report their minimum value as 1.47, drip irrigated land repot 1.56 as their minimum value. However, mean value of surface irrigated banana lands is 1.8 times higher than when compare the mean value of drip irrigated banana lands and it is significantly difference at one percent level. The surface irrigated lands reported 5.67 as their mean value, drip irrigated land show 3.12 as their mean value for total fertilizer usage based on proportion of recommended amount (Table 5.22). Utilization of low amount of chemical fertilizer in drip irrigated system, reflect higher ecological sustainability than surface irrigated banana.

Table 5.22 The proportion of total fertilizer usage in two systems based on recommendation amount

	Surface irrigated banana	**Drip irrigated banana**
Maximum	10.69	6.69
Minimum	1.47	1.56
Mean***	5.67	3.12
Standard deviation	2.01	1.08
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during2006

Normalized values for chemical fertilizer usage

The normalized values for chemical fertilizer utilization in surface irrigated banana system distribute from 0.00 to 1.00. However, greater parts of the farmer show

their normalized values for chemical fertilizer utilization 0.21 to 0.40, 041 to 0.60 and 0.61 to 0.80 ranges. It is 24, 37, and 24 percent from total farmers in surface irrigated banana system respectively. At the meantime normalized average value of drip irrigated lands is 1.6 time higher than surface irrigated value

Almost all the farmers who used drip irrigation to cultivate banana show their normalized values for chemical fertilizer usage are above 0.41. Large amount of farmers obtained normalized values for chemical fertilizer usage in 0.61to 0.80 range and 0.81 to 1.00 range. It is 46 percent and 48 percent respectively. Six percent of farmers show their normalized vales for chemical fertilizer utilization in between 0.41 to 0.60 rang . Normalized average values for two systems are significant at one percent level (Table 5.23).

Table 5.23 Farmers frequency of normalized of total chemical fertilizer utilization and normalized average values in two systems

Normalized indicator range	**Surface irrigated banana**		**Drip irrigated banana**	
	Number of farmers	%	**Number of farmers**	%
0.00 to 0.20	5	9.26	-	-
0.21 to 0.40	13	24.07	-	-
0.41 to 0.60	20	37.04	3	6.25
0.61 to 0.80	13	24.07	22	45.83
0.81 to 1.00	3	5.56	23	47.92
Total	54	100.00	48	100.00
Normalized average value* **	**0.50**		**0.78**	

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

When consider fertilizer usage in two systems most of the farmers in surface irrigated banana use extra amount of fertilizer because, fertilizer efficiency is low in this system due to soil moisture at drought period. Other thing is they use extra amount of water when they irrigate to their banana fields. Therefore, this additional water increases leaching of fertilizer. Consequently, farmers try to keep their yield applying high amount of fertilizer to their fields. This phenomenon will effect on ecology in negative way.

5.2.2.2 Annual agro chemical usage (AGCU)

However, different types of pest have been identified for banana, Banana weevil is main insect pest in this area. Banana weevil can create significant economic damage for banana cultivation. Therefore, farmers do not consider other pest attack. Their main concern is control of banana weevil. Department of agriculture does not recommend agro chemical to control banana weevil for matured plants. Field sanitation is recommended to prevent weevil attack as alternative for agro chemical. To determine the severity of the attack, carbofuran trap can be utilized. If attack is severe, 10 gram of carbofuran granule can be applied for one bush. However, it should not be done after flowering or any plant in the bush is very close to the flowering stage (DOA, 1998).

Carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methyl carbamate), a widely used systemic carbamate insecticide. Carbofuran is known to be a more persistent insecticide than other Carbamate or Organophosphorus insecticides. However, carbofuran was found to dissipate easily into the environment (Jui-Hung *et al.*, 1997). Carbofuran may cause cancer for human being and maximum limits for daily intake (according to guideline value derived by WHO) 7 µg / l. (Hamilton *et al.*, 2003).

Nevertheless, farmers use carbofuran to matured banana cultivation without concerning recommendations. From 102 surveyed farmers, 60 (59%) of farmers use Carbofuran directly to the soil. Even though, they use carbofuran with different trade

names, active ingredient (AI) concentration of the all substances are same. It is 3 gram per kilogram.

According to the survey results, in surface irrigated banana cultivation, 28 farmers (52%) used carbofuran in to soil and drip irrigated cultivations are used 32 farmers (67%). When consider maximum used amount of Corbofuran in surface irrigated system it is 50 kg per hectare. In case of drip irrigated lands maximum amount is 25 kg per hectare. In the both systems, minimum amount is zero. The average amount of carbofuran usage in both systems is more or less similar and it is significantly not different at five percent level (Table 5.24).

Table 5.24 Carbofuran utilization in two systems

	Surface irrigated banana (Kg/ha)	**Drip irrigated banana** (Kg/ha)
Maximum	50.00	25.00
Minimum	0.00	0.00
Mean [NS]	7.20	7.96
Standard deviation	9.77	7.20
Number of observations	54	48

Note: [NS] indicates that means are not significant difference at 5% level using t-test with equal variances

Source: Computed from field survey during 2006

Other commonly use agrochemical is herbicide. Form entire samples 20 percent of farmers use herbicide to control weed in their banana lands. Farmers who use chemical to control weed, almost all the farmer use gliphosate.

Gliphosate is non selective systemic herbicide. The toxicity of herbicide to plants is high, but its active substance, a glyphosate, decomposes rapidly. Thus, the herbicide is believed to be environmentally safe. However, glyphosate may inhibit microorganisms, thereby extending the duration of its decomposition and effects on various components of the soil microorganisms (Szarek *et al.*, 2000).

Farmers in surveyed samples use glyphosate with different trade name, but active ingredients of this all products are same level; 360 gram per litter. Among 54 farmers in surface irrigated banana system 22 percent of farmers use glyphosate to control weed their cultivations. But farmers in drip irrigated banana system eight percent of the farmers use glyphosate. Maximum used amount of glyphosete in surface irrigated system is 40 liters per hectare. In drip irrigated system maximum amount is 25 liters per hectare. The mean amount of Glyphosate usage in surface irrigated banana and drip irrigated banana are 3.90 liters per hectare and 1.25 liters per hectare in respectively. That mean values are significantly different in two systems at one percent level (Table 5.25). Low amount of agrochemical usage in drip irrigated banana cultivation imply, this cultivation has more ecological sustainability than surface irrigated banana cultivation.

Table 5.25 Glyphosete utilization in two systems

	Surface irrigated banana (l/ha)	**Drip irrigated banana** (l/ha)
Maximum	40.00	25.00
Minimum	0.00	0.00
Mean ***	3.90	1.25
Standard deviation	8.62	4.41
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Irrigation method highly influence on weed infestation of the banana field. Drip irrigation only wet surrounding area of the banana bush but surface irrigation wet entire soil surface of the banana field. This will enhance weed growing in the fields. To control weed in surface banana fields have to use more labor or chemical.

At the end utilization of labor and chemical surface irrigated banana fields are greatly increased.

When calculate total agro chemical usage in two systems, both carbofuran and glyphosate should be counted. However, these two substances have different unit. Therefore cannot be added directly. To mitigate problem that create adding different units, only glyphosate was considered. Because statistical test realized utilization of carbofuran in two systems is not significant at five percent level. Therefore, when calculate total agrochemical usage in two systems Carbofuran is not considered, because ecological effect from Carbofuran is similar in the two systems. So, only glyphosate is considered to calculate indicator for agrochemical usage in two systems.

Normalized value for agro chemical usage

Majority of the farmers in both system obtained higher level of normalized range in agro chemical utilization. In surface irrigation system it is about 82 percent and drip irrigated system it is about 92 percent. No one got in 0.00 to 0.20 and 0.21 to 0.40 classes in the drip irrigated banana farmers. Nevertheless, about two percent of farmers in surface irrigated lands are in 0.00 to 0.20 range. Same percentages in 0.21 to 0.40 range in surface irrigated banana farmers. About seven percent of farmers in surface irrigated banana cultivation obtained 0.41 to 0.60 range for normalized range for agrochemical. At the mean time, seven percent of farmers got 0.61 to 0.81 normalized range in the surface irrigated system. 4.16 percent of drip irrigated banana farmers are in 0.41 to 0.60 normalized range and same percentage of farmers in 0.61 to 0.80 normalized range.

When consider normalized average value for two systems, surface irrigated banana system has 0.90 and drip irrigated banana system has 0.96 normalized average values for agro chemical utilization (Table 5.26) and these averages are significant difference at one percent level.

Table 5.26 Farmers frequency of normalized of agrochemical utilization values and normalized average values in two systems

Normalized indicator range	Surface irrigated banana		Drip irrigated banana	
	Number of farmers	%	Number of farmers	%
0.00 to 0.20	1	1.85	-	-
0.21 to 0.40	1	1.85	-	-
0.41 to 0.60	4	7.40	2	4.16
0.61 to 0.80	4	7.40	2	4.16
0.81 to 1.00	44	81.50	44	91.68
Total	54	100.00	48	100.00
Normalized average value* **	**0.90**		**0.96**	

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.2.2.3 Soil salinity level in the banana fields (SS)

Salinity is common problems under irrigated agriculture especially in areas of low rainfall and high evaporative demand (Rietz and Haynes, 2003). Usually dry zone agro well are not very deep. Farmers extract shallow ground water using these wells. The shallow groundwater has higher electrical conductivity: EC) than the deep groundwater dry zone in Sri Lanka and the rate of soil evaporation during the dry season became very high (Song and Kayane,1996).

Banana grower use ground water to irrigate their cultivation. Salts that associated with ground water come to the soil surface when irrigation is occurred. Higher soil evaporation removes water from soil and remained salts on the soil surface. Based on this fact, groundwater irrigated banana lands have possibility to develop salinity in surface soil. The study used soil samples that were collected during

April to May year 2006 to test soil salinity. The soil salinity was detected by measuring electrical conductivity of the soil solutions.

Reported Maximum electrical conductivity in surface irrigated lands is 1.98 ds/m and minimum is 0.54 ds/m. But in drip irrigated lands reported 1.04 ds/m as their maximum soil electrical conductivity. Minimum electrical conductivity for drip irritated banana lands is 0.52 ds/m.

Even though, average electricity conductivity of surface irrigated banana lands (1.15 ds/m) is slightly higher than drip irrigated lands (1.04 ds/m), the statistically test clarified this difference is not significant at five percent level (Table 5.27).

Table 5.27 Results of the independent two sample t-test for electrical conductivity in banana fields

	Surface irrigated banana (ds/m)	**Drip irrigated banana** (ds/m)
Maximum	1.98	1.04
Minimum	0.54	0.52
Mean^{NS}	1.15	1.04
Standard deviation	0.37	0.28
Number of observations	54	48

Note: ^{NS} indicates that means are not significant difference at 5% level using t-test with equal variances

Source: Computed from field survey during 2006

Soil salinity developments in the two systems do not show significant difference. Song and Kayane (1996) gave clarification on phenomena of salt accumulation on dry zone surface soil in Sri Lanka. The soil water came to surface soil is easily evaporated during dry period, leaving dissolved salts near the soil surface. When the next rain comes, the infiltrated water dissolves the accumulated

salts during the process of percolation to the water table. These processes have been continuing for a long time, ever since the land was first deforested for agricultural use.

When we consider total annual rain fall in the district it about 1045 mm. Even though, ground water utilization of two irrigation methods may create differences on salt accumulation on the soil, at rainy season (October to mid of February) all accumulated salts may be leaching down from surface soil to deeper soil or to ground water table. The study used soil which collected at the just after two month of the main rain season and there was little rain during soil collecting time (April). These phenomena may cause the result of the ultimate salinity level of the banana fields.

Normalized values for soil salinity level

Both surface irrigated and drip irrigated banana systems spread their normalized values for salinity in banana field from 0.00 to 1.00. However, In the case of surface irrigated banana fields, 39 percent of banana field obtain normalized soil salinity values in between 0.61 to 0.80. 0.21 to 0.40 and 0.41 to 0.60 ranges contain 20 percent and 15 percent of total surface irrigated banana lands respectively. Lowest normalized indicator range contains only nine percent of the lands form surface irrigation system.

Majority of the drip irrigated banana fields show their normalized soil salinity values in between 0.61 to 0.80 range. It is 54 percent of the total drip irrigated banana fields. Seventeen percent of the drip irrigated land show their normalized soil salinity values in 0.81 to 1.00 range. 0. 21 to 0.40 and 0.41 to 0.60 ranges are included same percentage of farmers it is 13 percent. The lowest indicator range, 0.00 to 0.20 contain only four percent of total drip irrigated banana fields.

At the same time, normalized average value for soil salinity in both systems is not much difference. While surface irrigated lands show 0.57 as their normalized average value for soil salinity, drip irrigated land show 0.64 as their normalized average value (Table 5.28).

Table 5.28 Farmers frequency of normalized values of soil salinity and normalized average values for soil salinity in two systems

Normalized indicator range	Surface irrigated banana		Drip irrigated banana	
	Number of farmers	%	Number of farmers	%
0.00 to 0.20	5	9.26	2	4.16
0.21 to 0.40	11	20.37	6	12.5
0.41 to 0.60	8	14.81	6	12.5
0.61 to 0.80	21	38.89	26	54.17
0.81 to 1.00	9	16.67	8	16.67
Total	54	100.00	48	100.00
Normalized average value ^{NS}	**0.57**		**0.64**	

Note: ^{NS} indicates that means are not significant difference at 5% level using t-test with equal variances

Source: Computed from field survey during 2006

5.2.3 Agronomical sustainability indicators

These indicators reflect differences of agronomic sustainability of banana cultivation with two irrigation methods.

5.2.3.1 Weed infestation of the banana field. (WI)

Weed badly influence different ways on agriculture, main effect is yield reduction of the crop. Weed can reduce crop yield 10 percent to 25 percent (Rao, 2000). Therefore, weed control is one of major agronomic practice. If weed infestation is higher, weed control attempt should be higher to get good yield from crops.

Maximum weeding per year in surface irrigated banana lands is 10 and minimum weeding is three. Incase of the drip irrigated banana, maximum weeding frequency is five and minimum is one.

However, average weeding in surface irrigated banana land is two times higher than drip irrigated banana lands. While, surface irrigated banana lands repot 6.87 is their average weeding, drip irrigated banana lands show 3.37 as their average weeding during the year. These averages are significantly difference at one percent level (Table 5.29). This low value of weeding in drip irrigated banana cultivation imply, drip irrigated banana cultivation has higher agronomic sustainability than surface irrigated banana cultivation.

Table 5.29 Results of the independent two sample t-test for weeding frequency in banana cultivation

	Surface irrigated banana (Number of time / year)	**Drip irrigated banana** (Number of time / year)
Maximum	10	5
Minimum	3	1
Mean***	6.87	3.37
Standard deviation	1.56	0.98
Number of observations	54	48

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

Normalized values for weed infestation

Normalized values for weed infestation in two systems are contrast. Normalized weed infestation are condense in lower ranges in surface irrigated lands. Large part of the surface irrigated banana lands show their normalized weed infestation values in between 0.21 to 0.40 range it is 46 percent. 0.41 to 0.60 range

reported 33 percent from total surface irrigated lands. 13 percent of the surface irrigated banana fields obtained normalized weed infestation values in between 0.00 to 0.20. Their maximum range is 0.61 to 0.80; it is contained about eight percent of the farmers. No farmers in 0.81 to 1.00 range in this system.

When consider drip irrigated banana system, all most all the farmers are above 0.41. Greater part of the farmers is in 0.61 to 0.80 range, it is 73 percent of total drip irrigated banana farmers.

When consider normalized average value for weed infestation of the two systems, drip irrigated banana cultivation has double value than surface irrigation lands and it is significant difference at one percent level (Table 5.30).

Table 5.30 Farmers frequency of normalized values of weed infestation and normalized average values for weed infestation in two systems

Normalized indicator range	**Surface irrigated banana**		**Drip irrigated banana**	
	Number of farmers	%	**Number of farmers**	%
0.00 to 0.20	7	12.96	-	-
0.21 to 0.40	25	46.30	-	-
0.41 to 0.60	18	33.33	6	12.5
0.61 to 0.80	4	7.41	35	72.92
0.81 to 1.00	-	-	7	14.58
Total	54	100.00	48	100.00
Normalized average value* **	**0.35**		**0.73**	

Note: *** indicates that means are significant difference at 1% level using t-test with unequal variances

Source: Computed from field survey during 2006

5.2.3.2 Lodging tolerance of banana plants (LT)

Unlike other crops, banana farmers should pay attention to prevent lodging of the banana plants. If not it may cause to significant yield loss. Therefore prop supply is special agronomic practice in banana cultivation. If any farmer experienced, higher lodging rate of his cultivation, farmer try to protect his cultivation increasing prop supply. The study has used fallen rate and support supply rate to measure lodging tolerance in banana cultivation.

Both systems reported 100 percent as their maximum lodging tolerance. While surface irrigated banana showing 10 percent as their minimum lodging tolerance and drip irrigated banana lands show 81 percent as their minimum lodging tolerance rate.

Furthermore, average lodging tolerance of surface irrigated banana lands is a little higher than drip irrigated banana, the statistical test show this difference is not significant at five percent level (Table 5.31).

Table 5.31 Results of the independent two sample t- test for lodging tolerance of banana cultivation

	Surface irrigated banana %	**Drip irrigated banana %**
Maximum	100	100
Minimum	10	81
Mean [NS]	94	93
Standard deviation	13	5
Number of observations	54	48

Note: [NS] indicates that means are not significant difference at 5% level using t-test with quell variances

Source: Computed from field survey during 2006

Normalized values for lodging tolerance of banana plant

When consider normalized for lodging tolerance of banana plant in two system, both systems have similar feature. Ninety six percent of banana fields in both systems obtained their normalized value for lodging tolerance in between 0.81 to 1.0. While drip irrigated lands show four percent of normalized values for lodging tolerance in between 0.61 to 0.80, surface irrigated banana show two percent in this range. In drip irrigated banana, any fields are not bellow the 0.61. But surface irrigated banana two percent of farmers in 0.00 to 0.20 range. Normalized average values of two systems are not much difference and it is not significant difference at five percent level (Table 5.32).

Table 5.32 Farmers frequency of normalized values of lodging tolerance and normalized average values of lodging tolerance in two systems

	Surface irrigated banana		**Drip irrigated banana**	
Normalized indicator class	**Number of farmers**	%	**Number of farmers**	%
0.00 to 0.20	1	1.85	-	-
0.21 to 0.40	-	-	-	-
0.41 to 0.60	-	-	-	-
0.61 to 0.80	1	1.85	2	4.17
0.81 to 1.00	52	96.30	46	95.83
Total	54	100.00		100.00
Normalized average values [NS]	**0.94**		**0.92**	

Note: [NS] indicates that means are not significant difference at 5 % level using t-test with unequal variances

Source: Computed from field survey during 2006

5.3 Changing trend of sustainability indicators

During the field survey, farmers were inquired some experiences on changing trend of sustainability indicators and some relevant variables during last five years. Including amount of changing trend of water diverted, yields of banana, and other sustainability indicator, which can be directly observed by farmer, were asked at the survey.

5.3.1 Changing trend of water divert

In the surface irrigated banana cultivation, 24 percent of farmer experienced in changing trend of water divert in to banana cultivation and other (76%) said they have experience water divert was stable during last five year.

Most of the farmers who use drip irrigation to convey water from wells to banana plots had experience, water diverted banana cultivation has no changing trend. Eighty seven percent from drip irrigated banana farmers response is amount of water diverted was stable during last five year. Other 13 percent farmers experienced, water diverted during last five year has changing trend.

From those who have changing trend on water divert (13%) from drip irrigated banana, six percent of banana farmers have slightly decreasing trend and four percent had experienced moderately decreasing trend. Nevertheless, three percent of farmers said they had slightly increasing trend on water diverted in to banana cultivation (Table 5.33).

Table 5.33 Farmer response of changing trend of amount of water divert during last five year

Farmers response	Surface irrigation		Drip irrigation	
	Number of farmers	%	Number of farmers	%
No changing trend on water divert	**41**	**75.93**	**42**	**87.50**
Changing trend on water divert	**13**	**24.07**	**6**	**12.50**
Moderately decreasing trend	*-*	*-*	*2*	*4.17*
Slightly decreasing trend	*-*	*-*	*3*	*6.25*
Slightly increasing trend	*11*	*20.37*	*1*	*2.08*
Moderately increasing trend	*2*	*3.70*	*-*	*-*
Total	**54**	**100.00**	**48**	**100.00**

Source: Computed from field survey during 2006

5.3.2 Changing trend of banana yield

According to the experience of banana growers who use surface irrigation, only five percent of farmers had experience on changing trend of banana yields during last five years. From that, three percent of farmers said they had experience on moderately increasing their yield and other two percent had experience decreasing trend of large amount yield from their banana fields. Farmers who use drip irrigation

for banana cultivation, only 12 percent of had changing trend on banana yield and others (88%) expressed their yield is stable during last five years.

Among the farmers who had experience on changing trend on yield in drip irrigated banana cultivation (12%), six percent of farmers had experience banana yield was increasing in moderately other six percent said their yield as increasing slightly during last five years (Table 5.34).

Table 5.34 Farmer response of changing trend of banana yield during last five years

Farmers response	**Surface irrigation**		**Drip irrigation**	
	Number of farmers	%	Number of farmers	%
No changing trend on banana yield	**51**	**94.44**	**42**	**87.50**
Changing trend on banana yield	**3**	**5.56**	**6**	**12.50**
Highly decreasing trend	*1*	*1.86*	-	-
Moderately decreasing trend	-	-	-	-
Slightly decreasing trend	-	-	-	-
Slightly increasing trend	-	-	*3*	*6.25*
Moderately increasing	*2*	*3.70*	*3*	*6.25*
Total	**54**	**100.00**	**48**	**100.00**

Source: Computed from field survey during 2006

5.3.3 Changing trend of social participation

Fifteen percent of farmers in surface irrigated banana had experience on irrigation method influence to time allocation on their social activities. Others (85%) said no effect on time allocation on social activities of the irrigation method.

Twenty nine percent of farmers in drip irrigated banana cultivation had feeling, irrigation method influence on time allocation of their social activities. Others (71%) said time allocation on social activities and irrigation method is not related (see Table 5.35).

Table 5.35 Farmer response of effect of irrigation method for time allocation on social activity in last five year

Farmers response	**Surface irrigation**		**Drip irrigation**	
	Number of farmers	%	Number of farmers	%
Irrigation method not effect on social activity	**46**	**85.19**	**34**	**70.83**
Irrigation method effect on social activity	**8**	**14.81**	**14**	**29.17**
Highly decreasing trend	*1*	*1.85*	-	-
Moderately decreasing trend	-	-	-	-
Slightly decreasing trend	*3*	*5.56*	-	-
Slightly increasing trend	*4*	*7.40*	*4*	*8.33*
Moderately increasing trend	-	-	*10*	*20.84*
Total	**54**	**100.00**	**48**	**100.00**

Source: Computed from field survey during 2006

Surface irrigation farmers who had experience on the irrigation method has effected on time allocation on social activities, seven percent of the farmers faced slightly increasing trend and six percent farmers had faced slightly decreasing trend. Other one percent experience largely decreeing trend.

From 29 percent of farmers in drip irrigated banana system who gave response on their irrigation activities effect on social activities, 21 percent of farmers had idea; irrigation method moderately increased their time allocation on social activities. Other eight percent said they have experience, irrigation method slightly increased time allocation on social activities (see Table 5 .36).

5.3.4 Changing trend of chemical fertilizer usages

When we consider the farmers who cultivate banana with surface irrigation method, seven percent of farmers had experience, changing trend on their fertilizer utilization and other said no changing trend on their fertilizer usage.

Forty six percent of drip irrigated banana growers had experience, their fertilizer usage had changing trend during last five years and others (54%) said no changing trend (Table 5.36).

Table 5.36 Farmer response of changing trend on chemical fertilizer usage during last five years

Farmers response	Surface irrigation		Drip irrigation	
	Number of farmers	%	Number of farmers	%
No changing trend on chemical fertilizer utilization	50	92. 59	26	54.17
Changing trend on chemical fertilizer utilization	4	7.41	22	45.83
Total	54	100.00	48	100.00

Source: Computed from field survey during 2006

This trend depends on the type of the fertilizers. Some farmer has experience-changing trend on all type of fertilizer, some had only urea and some had changing trend on urea and MOP utilization.

Chaining trend of difference type of fertilizer

In surface irrigated banana farmers, who had experience on changing trend on fertilizer utilization (4%), only one percent have experience all fertilizer usage had changing trend during last five year. two percent farmers said they had experience on changing trend on utilization of urea, one percent of farmer had experience on changing trend of both MOP and urea fertilizers. However, no one had experience of changing trend on only MOP fertilizer.

In drip irrigated banana, farmers who had experience on changing tend on utilization of chemical fertilizer (46%), 11 percent of farmers said they had experience on utilization of all type of fertilizer and 29 percent of farmers said they had experience on changing trend of urea utilization during last five years. Four

percent of farmers had experience on changing trend of both MOP and urea fertilizers. Only one farmer said (2%) they had experience on MOP fertilizer utilization had changing trend (Table 5.37).

Detail on all fertilizer utilization trend

In the surface irrigated banana farmers, only about two percent have experience all fertilizer usage had changing trend, this two percent farmer said they had slightly increasing trend of all fertilizer usage during past five years.

In drip irrigated banana farmers, from 10 percent farmers who experienced on changing trend of all fertilizer usage for their banana fields. From that, six percent farmers said they had experience all chemical fertilizer utilization has moderately decreasing trend. Two percent of farmers had slightly decreasing trend and other two percent of farmers said they had experience, slightly increasing on all chemical fertilizer utilization for their banana cultivation (Table 5.37).

Detail of urea utilization trend

About four percent of farmers in surface irrigated banana cultivation had experience on changing trend on urea utilization. They all said they had experience moderately increasing trend on urea utilization past five years.

In drip irrigated banana filed, 29 percent of farmers had experience changing trend on urea utilization. From that 17 percent of farmers said they have experience moderately decreasing trend and four percent of farmers have slightly decreasing trend of urea utilization. However, eight percent of farmers have experience, utilization of urea in to their banana field have slightly increasing trend during past five years (Table 5.37).

Table 5.37 Detail of chemical fertilizer utilization trend in two systems

Detail	Surface irrigation		Drip irrigation	
	Number of farmers	%	Number of farmers	%
All fertilizer utilization has chaining trend	**1**	**1.85**	**5**	**10.42**
Moderately decreasing	-	-	*3*	*6.26*
Slightly decreasing trend	-	-	*1*	*2.08*
Slightly increasing trend	*1*	*1.85*	*1*	*2.08*
Urea has chaining trend	**2**	**3.71**	**14**	**29.17**
Moderately decreasing trend	-	-	*8*	*16.67*
Slightly decreasing trend	-	-	*2*	*4.17*
Slightly increasing trend	-	-	*4*	*8.33*
Moderately increasing trend	*2*	*3.71*	-	-
MOP has chaining trend	**-**	**-**	**1**	**2.08**
Moderately decreasing trend	-	-	*1*	*2.08*
Urea and MOP has chaining trend	**1**	**1.85**	**2**	**4.16**
Moderately decreasing trend	-	-	1	2.08
Slightly decreasing trend	1	1.85	1	2.08
Slightly increasing trend	-	-	-	-
Total	**4**	**7.41**	**22**	**45.83**

Source: Expansion from Table 5.36

5.3.5 Changing trend of agro chemical usages

In surface irrigated banana fields, five percent of farmers have experience changing trend of utilization of agro chemical for their field and all farmers experienced changing trend of insecticide (carbofuran) usage only. They all said they had experience on slightly increasing trend on carbofuran utilization on their banana field.

Farmers who are growing banana with drip irrigation, four percent said they have experience changing trend on agro chemical utilization for their banana fields. This all farmers experienced only changing trend on insecticide (carbofuran). From that, two percent of farmers said they have experience slightly increasing trend and other two percent said they faced highly decreasing trend on utilization of carbofuran for their banana fields (Table 5.38).

Table 5.38 Changing trend of agrochemical utilization in two system

Detail	**Surface irrigation**		**Drip irrigation**	
	Number of farmers	%	Number of farmers	%
No changing trend on agro chemical utilization	**51**	**94.55**	**46**	**95.83**
Changing trend on agro chemical utilization	**3**	**5.55**	**2**	**4.17**
Highly decreasing trend	-	-	*1*	*2.08*
Slightly increasing trend	*3*	*5.55*	*1*	*2.08*
Total	**54**	**100.00**	**48**	**100.00**

Source: Computed from field survey during 2006

5.3.6 Changing trend of weed infestation

Among the surface irrigated banana growers, only three percent of farmers have experience on changing trend of weed infestation of their banana fields. From that, all farmers faced slightly decreasing trend of weed infestation

Twenty five percent of farmers in drip irrigated banana system said they have experience; weed infestation of their banana field had changing trend during last five years and the entire farmers faced only moderately decreasing trend on weed infestation (Table 5.39).

Table 5.39 Changing trend of weed infestation in two system

Detail	Surface irrigation		Drip irrigation	
	Number of farmers	%	Number of farmers	%
No changing trend on weed	**52**	**96.30**	**36**	**75.00**
Changing trend on weed infestation	**2**	**3.70**	**12**	**25.00**
Slightly decreasing	*2*	*3.70*	-	-
Moderately decreasing	-	-	*12*	*25.00*
Total	**54**	**100.00**	**48**	**100.00**

Source: Computed from field survey during 2006

5.3.7 Changing trend on lodging rate and prop supply rate

When doing field survey farmer were asked on experience on trend of prop supply and lodging rate. However, no one has experience changing trend on prop supply and lodging rate of banana in both systems. Entire farmers said falling rate of banana and support supply rate are not changing during last five years.

5.4 Stakeholders weighting for sustainability criteria and sustainability indicators.

Two stakeholder workshops were conducted to obtain weights for sustainability criteria and indicators. At the both workshops participant gave, same priorities on sustainability criteria (see Chapter III). After giving priorities on criteria, they were asked to do pairwise comparisons on criteria. Using this pairwise comparison, weights for the criteria were calculated and consistency of the decision was checked. Second step was calculating weights for sustainability indicators. Same procedure was fallowed to calculate weights for the indicator. When they are giving priority on indicator under socio economic and agronomic criteria, they gave same priories, but under ecological criteria, stakeholder in drip irrigated banana cultivation gave first priority on chemical fertilizer usage and second priority on agrochemical usage. Surface irrigated banana cultivation farmers gave first priorities on agro chemical usage and second priority on chemical fertilizer usage.

Both stakeholder gave lest priority on soil salinity (see Chapter III). At the end of the both workshops, weights for the criteria and indicator were obtained.

After calculating weights for sustainability criteria and sustainability indicator, using these weights final weights for the sustainability indicator were calculated. Calculated final weights for sustainability criteria and indicators are in Table 5.40 (Weights calculation procedure in Appendix 3).

Table 5.40 Calculated final weights for sustainability criteria and indicator at workshops

	Surface irrigation			Drip irrigation		
Criteria	**Weight**	**Indicator**	**Weight**	**Weight**	**Indicator**	**Weight**
Socio economic	0.66	NP	0.42	0.70	NP	0.38
		WP	0.13		WP	0.19
		IV	0.07		IV	0.08
		SOP	0.04		SOP	0.05
Agronomic	0.26	WI	0.22	0.23	WI	0.15
		LT	0.04		LT	0.08
Ecological	0.08	CFU	0.02	0.07	CFU	0.04
		AGCU	0.05		AGCU	0.02
		SS	0.01		SS	0.01

Source: Computed from field survey during 2006

5.5 Overall sustainability of drip and surface irrigated banana cultivation

5.5.1 Normalized average values for indicator

To calculate sustainability index for the systems, individual normalized indicators should be converted to average values of the systems. Considering each indicator separately, average value of normalized indictor were calculate for two systems. Before calculate the overall sustainability index for the systems, using these normalized average value system can be compared for each criteria based on sustainability. If normalized average value of the indicator has higher value it implies higher sustainability.

Average normalized values for net profit (NP) in drip irrigated banana and surface irrigated banana are contrast. Approximately, drip irrigated banana field show three fold higher value than surface irrigated banana. When drip irrigated banana

report 0.50 for normalized average value for NP, surface irrigated banana demonstrate 0.15 as their normalized average value for NP.

Drip irrigated banana fields have three fold higher normalized average value for water productivity (WP) than surface irrigated lands. While drip irrigated report 0.55 as their normalized average for WP, surface irrigated lands show 0.17 as their normalized average for WP.

Normalized average value for income variation (IV) for drip irrigated banana fields show four fold higher value than surface irrigated banana. Normalized average value for drip irrigated banana lands is 0.86 and for surface irrigated banana lands is 0.22.

Normalized average values for farmer social participation rate (SOP) are not much different between two systems. While drip irrigated banana grower show their normalized average value for SOP as 0.86 surface irrigated banana grower repotted 0.79.

Drip irrigated banana lands demonstrate 0.78 as their normalized chemical fertilizer usage (CFU) and surface irrigated banana lands report 0.50 as their normalized average CFU.

Drip irrigated banana lands have 0.96 for normalized value for agro chemical usage (AGCU) and surface irrigated land have 0.90 as their normalized average value for AGCU.

While drip irrigated banana cultivation show their normalized average value for soil salinity (SS) is 0.64 surfaces irrigated banana lands show 0.57 for their normalized average value.

Normalized average value for weed infestation (WI) in drip irrigated banana lands is twice than surface irrigated banana lands. When drip irrigated reported normalized average value for WI is 0 .73 surface irrigated banana shows 0.35.

Normalized average values for lodging tolerance of banana plant (LT) are not contrast in two systems. While drip irrigated banana show, normalized average LT is 0.92 surface irrigated banana shows 0.94 (see Table 5.41).

Normalized value for indicator reflects level of sustainability. If value is close to one it means level of sustainability of indicator is high. If value is close to zero, level of sustainability of indicator is low. Therefore, these normalized average values of indicators can be utilized to compare two irrigation systems under banana cultivation.

Table 5.41 Normalized average values for each indicator in two systems

Indicator	**Surface irrigated banana**	**Drip irrigated banana**
Net profit	0.15	0.50
Water productivity	0.17	0.55
Income variation	0.22	0.86
Farmer social participation	0.79	0.86
Chemical fertilizer	0.50	0.78
Agrochemical utilization	0.90	0.96
Soil salinity level	0.57	0.64
Weed infestation	0.35	0.73
Lodging tolerance of banana plant	0.94	0.92

Source: Computed from field survey during 2006

To convenient to presenting and understanding, these values can be presented as graphs. The spider diagram which representing all normalized average indicators for two systems are demonstrating in Figure 5.2.

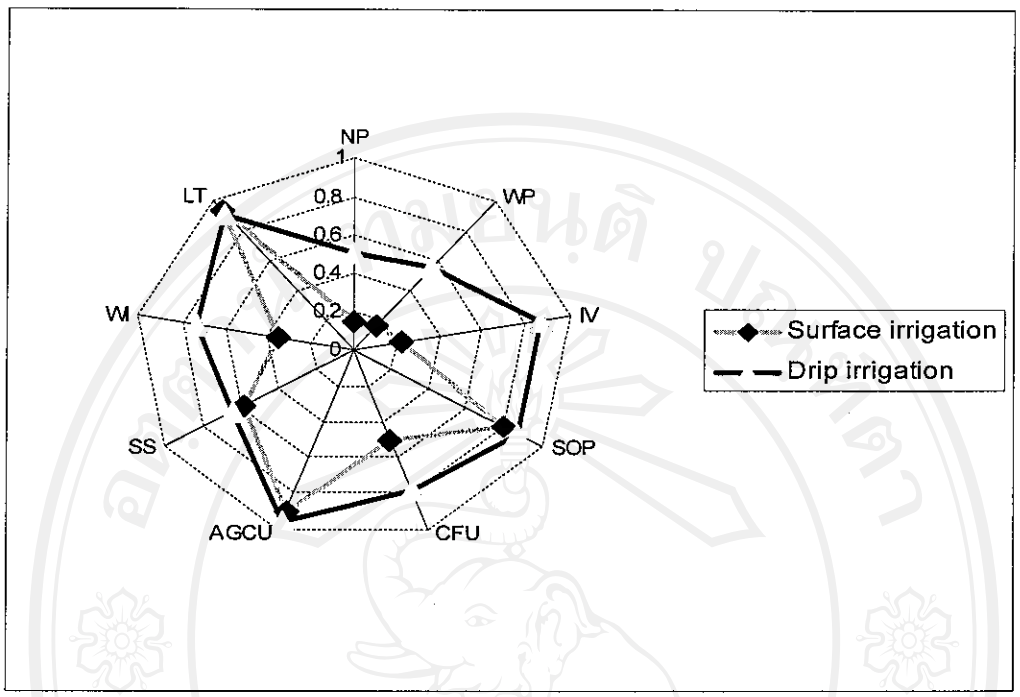

Figure 5.2 Comparison of normalized average indicators in two irrigation methods under banana cultivation

Source: Computed from field survey during 2006

5.5.2 Overall Sustainability index for the systems

Final aim is the study is comparison of overall sustainability of the two irrigation methods under banana cultivation. To fulfill this objective, using normalized average values of indicators, constructed overall sustainability index for the systems. For that each normalized average value multiplied with relevant weights, which were calculated by using information that was provided at stakeholder workshops. Then all normalized average weighted indicator values combined at the system level. The results are demonstrated in Table 5.42. While drip irrigated banana obtained 0.64 as their overall sustainability, surface irrigated banana demonstrate 0.32 as their overall sustainability index. The results show drip irrigated banana cultivation system has higher overall sustainability index than surface irrigated banana cultivation system.

Table 5.42 Overall sustainability index for two systems

Indicator	Surface irrigated banana			Drip irrigated banana		
	Average Normalized Value	Weight	Weighted Average normalized value	Average Normalized value	Weights	Weighted Average normalized Value
NP	0.15	0.42	0.06	0.50	0.38	0.19
WP	0.17	0.13	0.02	0.55	0.19	0.10
IV	0.22	0.07	0.02	0.86	0.08	0.07
SOP	0.79	0.04	0.03	0.86	0.05	0.04
CFU	0.50	0.02	0.01	0.78	0.04	0.03
AGCU	0.90	0.05	0.05	0.96	0.02	0.02
SS	0.57	0.01	0.01	0.64	0.01	0.01
WI	0.35	0.22	0.08	0.73	0.15	0.11
LT	0.94	0.04	0.04	0.92	0.08	0.07
SUS. Index			**0.32**			**0.64**

Source: Computed from field survey during 2006