**Tropical Agricultural Research Vol. 28 (4): 364 – 374 (2017)**

# Evaluation of Field Layout for the cultivation of Other Field Cropsin BayawaMinor Irrigation Systemin Sri Lanka

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**ABSTRACT:** *Minor irrigation systems are very unique to Sri Lankan agriculture for centuries for its role in food security, livelihood and ecosystem sustainability. The objective of this study was to evaluate constraints and potentials of paddy field system layout in a minor irrigation system for other field crop (OFC) cultivation. The study was done in Bayawa minor irrigation system, in Sri Lanka during 2014 and 2015. Data were collected and analyzed to evaluate, system components and their sustainability, canal uniformity, accessibility, and land and farmer plots distribution in the command area. Results according to the system layout reveal that, irrigation canals' uniformity varies along with the distance from head to tail endswith a water conveyance efficiency of 60%. Canal depth increases mainly due to sand mining, thus,requires a large amount of irrigation water for maintaining a hydraulic head in canals in order to supply irrigation water to fields under gravity. Positive hydraulic head of the right canal up to 70% of its length facilitates water distribution from canal to fields, but negative hydraulic head of the left canal constrains for that. As of the system layout and canal distribution, plot to plot irrigation is the common practice in the command area. The number of plots vary from 2-19 with the highest frequency of 6 plots. Cultivation of OFCrequires individual access to water to each plot. Hence, this irrigation and drainage system restrict OFC cultivation. Furthermore, 56% farmers hold less than 0.4 ha farmer fields due to land fragmentation over the years. This also leads to, low accessibility of individual field plots to irrigation canal and identified as major constraint to OFCcultivation.*

***Keywords:****Drainage, hydraulic head, irrigation, minor tanks, other field crops*

## INTRODUCTION

### Paddy cultivation in minor tanks

Minor irrigation systems under tanks' cascade are very unique to Sri Lankan agriculture for centuries for its role in food security, livelihood and ecosystem sustainability. There were about 30,000 minor tanks (MTs) in Sri Lanka (Medagama, 1982) of which only about 10,000 tanks are in operationat present (Henegedara, 2002). *Kurunegala* district has the highest

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number of MTs (1298) (Panabokke*et al*., 2002). Current estimates reveal that, out of 520,000 ha of irrigated lands in Sri Lanka, 192,085 ha are under MTs (Aheeyar, 2013). This is a considerable portion (nearly 37%) of the country's agricultural lands, which is capable of contributing to the gross national production. Further, a higher number of rural population depends on MTs for their livelihoods (Somasiri, 1991). A greater attention, therefore, is needed in improving the farming for a sustainable agricultural production and rural livelihood underMTs. Tank water supply depends on rainfall (RF), runoff, catchment size, tank density, soil properties, topography, and land use in the area and water conservation measures in the catchment (Somasiri, 1991).While MTs catchment area remaining constant, the command areas have expanded at tail ends in most cases. However, there are several problems related to land and water productivity and cropping intensity (CI) under MTs when compared to major irrigation systems. The land productivity under MTs is much lower than that of the major irrigation schemes (Begum, 1987). Cropping intensity in the *Yala* season ranges from 8 to 83% in the districts of the intermediate zone (IZ) (Somasiri, 1991) and in some years, cropping is not possible at all. Some of the reasons for such low CIs and the variability of cultivated area from season to season are;too large command area per unit of stored water in a tank, low irrigation potential of the tank, and inadequate catchment area to provide adequate runoff.When the ratio of catchment area to tank area is high at full supply level, the irrigation water supply from the tank is more stable. According to Somasiri(1991), catchment area available for one ha-m of storage capacity of a tank ranges from 3 to 18 ha, and when it is less than 9 ha, the irrigation potential of that particular tank is very low.

Paddy is the major crop cultivated under MTs using RF and/or water issued from the tanks. The reliability of water issued from a tank depends on the water storage from the previous season. Annual RF in the dry zone (DZ) follows a bimodal pattern with a longer rainy season (*Maha*season) with high amount of runoff and a shorter rainy season (*Yala*season) with less runoff. The most critical problem in MTs is severe water scarcity during the*Yala* season (Dharmasena, 1996). However, insufficient RF even during *Maha* season has also been reported (Fernando, 1981; Wijayarathna*et al*., 1994). Dharmasena (1989) reported that farmers need to wait until the tank gains adequate water storage for cultivation since RF is uncertain sometimes even in the *Maha* season. Chandrasiri*et al*. (2014) found that farmers in *Awlegama* had abounded many major seasons and all in-between seasons (periods between major seasons) without cultivating paddy even with enough irrigation water in the tank to cultivate OFC. Therefore, it is evident that during most part of the year, fields in the DZ and IZ remain idle because of insufficient water for paddy cultivation. When the tank fails to reach its full capacity, command areas under a large number of MTs are kept fallow resulting low CI. However, the recommendation of the Department of Agrarian Development (DoAD) is to cultivate OFCs under such circumstances.

Farmers practice crop diversification (CD) or OFC cultivation in paddy fields from long time back targeting higher income and better living standards. However, the benefit of CD is limited by several factors. Farmers grow OFC in minor irrigation schemes by avoiding the short rainy period (April- May) in the dry season to protect the crop from flooding (Jayawardane and Weerasena, 2000). There is a potential for growing OFC using residual moisture and remaining water in the tank in paddy fields (Liyanage*et al*., 1994). Wijayarathne (1996) reported that CIs in minor irrigation systems are stagnant around 1.1 or below from 1982 because farmers do not cultivate OFC in the command area due to many technical and socio-economic reasons. On the other hand, CD can also be considered as an adaptation strategy for climate change, food security and livelihood development.

## Objective

The objective of this study was to assess the constraints and potentials of the paddy field system layout in a selected MT for OFC cultivation during two major cultivation seasons and in-between seasons.

## METHODOLOGY

### Study area

The study was conducted during the period from February 2014 to February 2016in the *Bayawa* minor irrigation system ($7^0$ 69'N; $80^0$ 20'E), in the Kurunegala District of Sri Lanka. The system is located in the *Awlegama GramaNiladhari* (GN) Division of theWariyapola Divisional Secretariat (DS) Division in Kurunegala (Fig. 1). The study area belongs to IL3 agro-ecological zone with an annual RF range of 1750 - 2500 mm (DOA, 2006). Fig. 1 illustrates distribution of the canal systems in the command area. Both right canal (RC) and left canal (LC) are on contours at higher elevation to supply irrigation water to fields located in between these two canals. The middle canal (MC) is primarily a drainage canal passing through middle of the command area.

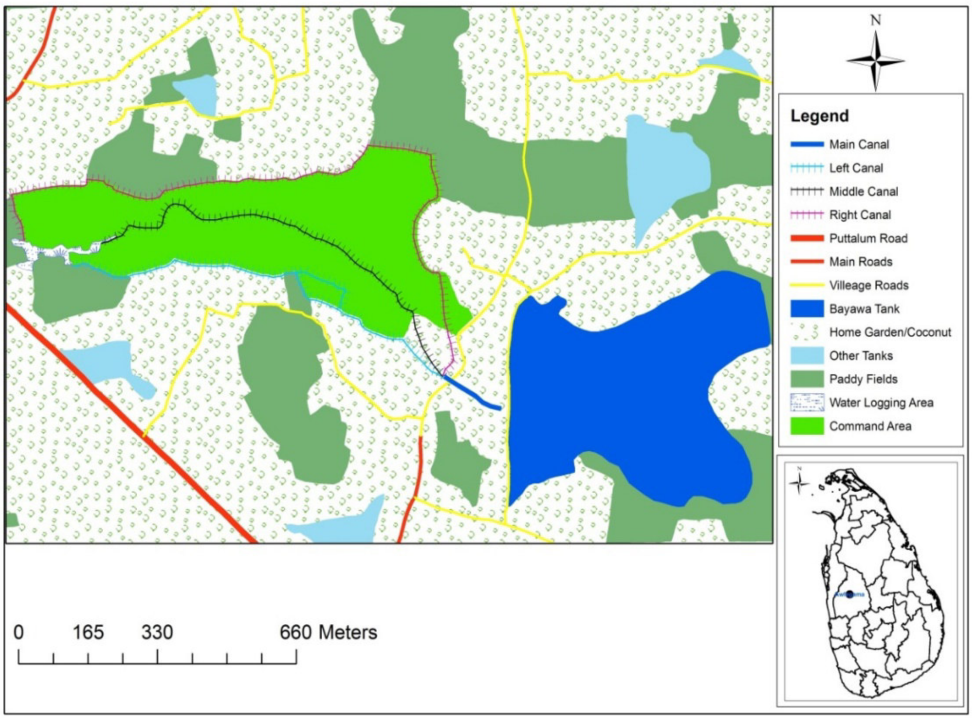


**Fig. 1. Map of the *Bayawa* minor irrigation system and the canal system**

### System component assessment

The entire system was mapped and respective areas and lengths were measured by using Arc GIS (10.2 version software). Ratios between the catchment area (ha) and tank's water spread areas at full supply level (ha) were calculated for the*Bayawa* tank.

**Land and farmer plots distribution in the command area**
Land distribution and field operations were evaluated by using secondary data obtained from *Awlegama*DoAD Division, and by field observations and focus group discussions during the study period. Distribution of farmer fields was evaluated by mapping the individual farmer fields and calculating the number of individual farmer's plots. The entire command area was divided into six sections based onthe location (head (H), middle (M) and tail (T)) and left and right sides of the MC (Fig. 1).

**Canal uniformity and accessibility**
The geometry of two irrigation canals and one drainage canal was extracted by measuring average depth, width and elevation of each canal.Elevationsat number of selected locations along each canal (RC=25, MC=15 and LC=12), approximately at 80 m interval from head to tail ends were measured. In addition, irrigation water issues were measured employing the area-velocity method using a current meter (Geopacks stream flow meter MFP51). The water depth andflow rate relationships were developed for each channel. Water flows in each canal were recorded during dates of water releases and the total seasonal water issue was calculated. Water conveyance efficiencies for RC and LC canals were calculated using the difference in water flow from the head end to the tail end in a day of no field water applications.

Farmer's accessibility to canal water and drainage system was evaluated by using elevation data at selected locations of each canal and the command area. Accessibility to command area, individual farmer fields and canal system was evaluated by mapping the entire study area using Arc GIS (10.2 versions).

## RESULTS AND DISCUSSION

System components, canal geometry, drainage system and field-plot layout were investigated with regard to the suitability for OFC in terms of water availability, accessibility, and supply and drainage.

**System capacity and accessibility**
Water storage in the tank depends on the RF and runoff from the catchment area. The catchment and the command area are 271 and 30 ha, respectively. The tank's capacity at full supply level is 31 ha-m and water spread area is 20.8 ha. The ratio between the catchment area and tank's water spread area at full supply level is 13.03. Since the ratio is more than 9, the potential for irrigation from the tank is high for OFC cultivation. In general, OFC requires less amount of water than paddy.

Unlined RC and LC canals run along the right and left boundaries of the command area and supply water only to one side of each canal. The RC covers 55% of the command area and supply irrigation water to the highest number (520) of individual plots (Table 1). The MC runs at the lowest elevation of the command area. This canal mainly serves as drainage canal, with limited water supply to some field plots. The MC should facilitate the quick drainage, which is essential for OFC in case of excess RF.

**Table 1. Canal measurements**

| Canal | Length (km) | Number of plots covered by irrigation | Command area (ha) |
|---|---|---|---|
| RC | 1.96 | 520 | 16.5 |
| LC | 1.20 | 225 | 9.0 |
| MC | 1.06 | 146 | 4.5 |

**Canal geometry and water distribution**

Canal width, depth and carrying capacity are important to understand the effectiveness of water distribution. According to canal configuration,all three canals have slope less than 1%, which is adequate enough for water distribution under gravity (Table 2).

The average water conveyance efficiencies were calculated separately for RC and LC.The RC, which serves 55% of the command area has 60 % conveyance efficiency with an average flow rate of 0.55 $m^3/s$. The same efficiency was obtained for the LC with an average flow rate of 1.03 $m^3/s$. However, the conveyance efficiency within the each section was not quantified. Data reveal that canals have the capacity to irrigate respective areas.

**Table 2. Geometry of the three major canals and their capacities**

| Canal | Average width (m) | Average depth (m) | Slope (%) | Average cross section area ($m^2$) | Average velocity ($ms^{-1}$) | Average flow rate ($m^3s^{-1}$) | Mean water conveyance efficiency (%) |
|---|---|---|---|---|---|---|---|
| RC | 2.05 | 0.40 | 0.21 | 0.82 | 0.67 | 0.55 | 60 |
| MC | 2.49 | 0.61 | 0.79 | 1.52 | 1.33 | 2.02 | - |
| LC | 1.68 | 0.50 | 0.65 | 0.84 | 1.23 | 1.03 | 60 |

As shown in Fig. 2, the cross sectional areas of all three canals highly vary with distance from the tank. The RC and LC have similar cross sections while the MC has the highest average cross section (Table 2). At the head end, the MC has a comparatively higher cross sectional area than in middle and tail ends. Since the main purpose of the MC is drainage, the cross sectional area of this canal should be increased towards the tail end. The LC approximately has a constant cross section at the head end while it varies highly at middle and tail ends. The cross sectional area of irrigation canals generally reduces along the distance and therefore the carrying capacity reduces. However, it is not the case in the *Bayawa* irrigation system. As a result, a higher discharge rate is required to obtain the required hydraulic head to supply water to fields under gravitational flow. Major disadvantages of highly variable cross sections are;

(i) reduced water depth leading to less accessibility to canal water by farm fields
(ii) frequently changing flow rates due to highly variable velocities

With these varying cross sectional areas and subsequent hydraulic heads, irrigation scheduling becomes a challenging task since some farmers fulfill their water requirement within a short period of time while others have to wait for long.

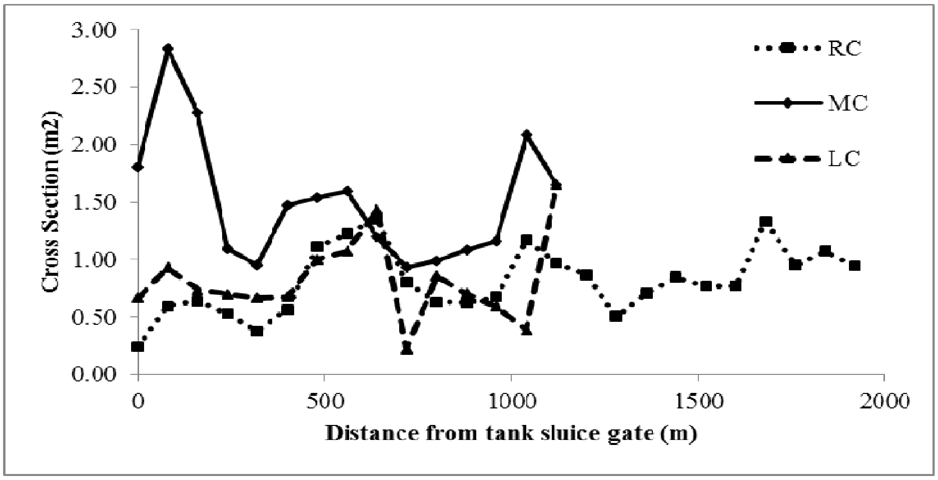


**Fig. 2. Variability of canal cross sectional area with distance**

**Accessibility to canal water**
Water is distributed from the tank to canals and then to fields by gravitational flow. Therefore, water levels in canals should be higher than levels in field plots to maintain the necessary hydraulic head. The maximum hydraulic head difference can be obtained when the water level in the canal is at full supply level.

In this study, three scenarios were observed as shown in Fig. 3. The first scenario (Fig. 3a, 3c and 3e) is ideal for irrigation since the field ground level is always lower than the canal bottom levels. Second scenario (Fig. 3b and 3d) shows that the field ground level is higher than the canal bottom level. The third scenario, (Fig. 3b, 3c, 3d and 3e) has different bund heights either side of the canals. In a parallel study, Chandrasiri*et al.* (2014) reported conflicts among farmers during the time of irrigation even with a high amount of water flowing in the canal. This situation arises when farmers convey irrigation water to their own fields by blocking the main canal at places as shown in Figures 3b and 3d. These farmers need to increase the hydraulic head to distribute water to their fields and therefore farmers at tail end do not receive enough water leading to conflicts among farmers.

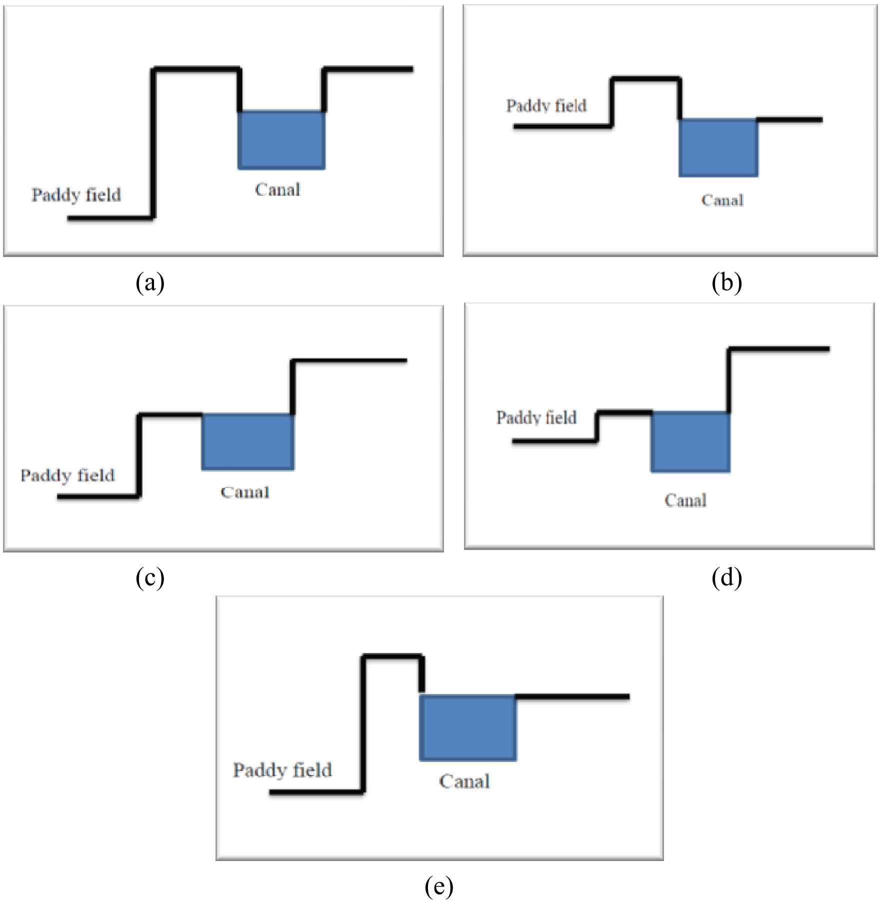


**Fig. 3. Schematic diagrams for existing scenarios between paddy field and the canal**

Fig. 4 shows, the variation of hydraulic head difference in each canal with the distance. A positive hydraulic head difference means that water can be easily distributed to the field while a negative value indicates the difficulty of conveying water. The RC has a positive hydraulic head difference for more than 70% of its distance, while the latter part of the head end and a part of the middle section have negative hydraulic head differences. Farmer fields located closer to these negative hydraulic head points have difficulty in accessing canal water. According to field observations, this situation is a result of sand mining from all three canals during rainy seasons. In this system, the MC acts as a drainage canal and more than 73% of its distance havea negative hydraulic head difference to facilitate drainage of the command area. However, a positive hydraulic heads could be observed in some parts in middle and tail end sections. This situation is a constraint to drain excess water and lead to poor drainage, which is not suitable for OFC cultivation. The situation with respect to hydraulic head differences of the LC is generally not suitable for water application to respective fields.Farmers are unable to convey water to their fields without artificially increasing the hydraulic head except at two points closer to the tail end of the LC. In this situation, farmers generally convey water to fields by blocking the canal to increase the water level and then installing pipes. Farmers at lower parts of the respective canal do not get enough water and this leads to conflicts between farmers.

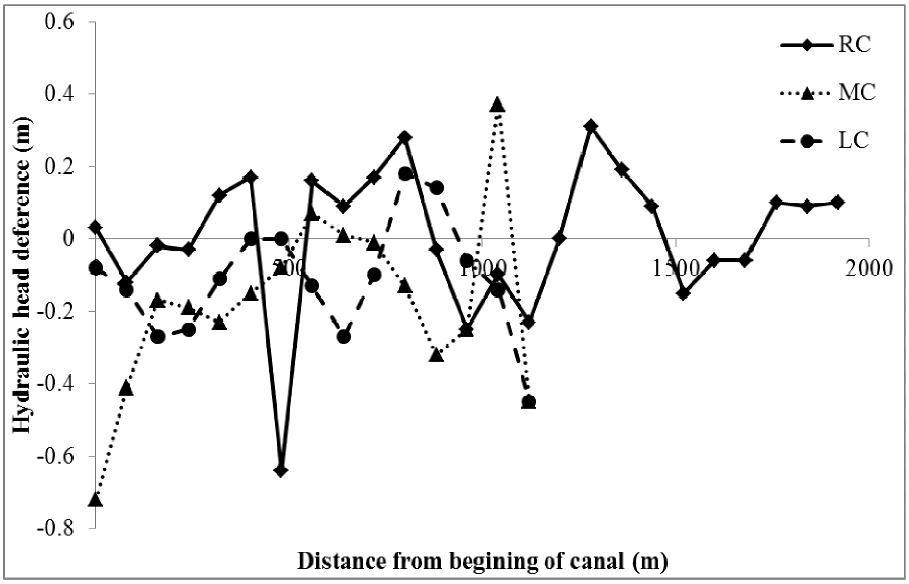


**Fig. 4. Hydraulic head difference between the canals and fields with distance**

**Drainage system in the command area**

The elevation deference between fields and the canal, slope and flow rate of the canal determine the effectiveness of the drainage system. As shown in Table 2, the slope of the MC is low for the drainage canal. As shown in Fig. 4 the hydraulic head is negative except two locations. According to measured average elevation of the field, two areas (head right and tail right) have no elevation difference while other four areas (head left, middle left, middle right and tail left) have 1 m elevation difference with the MC. Stagnated water was observed throughout these two head right and tail right areas even without irrigation and RF. Thus, this MC does not function properly to remove excess water, which leads to a water logging conditions in the command area and not suitable to OFC.

**Irrigation canals and plot numbers**

Irrigation and drainage is accomplished by allowing water to flow from plot to plot towards the MC from LC and RC. As shown in Fig. 5, the plot numbers involved in irrigation ranges from a minimum of 2 to a maximum of 19 with a mode value of 6 plots. Plot to plot irrigation is not a serious problem in paddy cultivation. However, OFC cultivation requires individual plot accessibility to irrigation canals or irrigation water regardless of length or width of the plot in the direction of irrigation. Fields located at lower elevations cannot be used for OFC since drainage water is frequently accumulated. Therefore, this draining system is not suitable for OFC cultivation because different farmers may cultivate different crops in different time periods. The amount, timing and duration of water supply can be varied from plot to plot negatively affecting the growing crops.

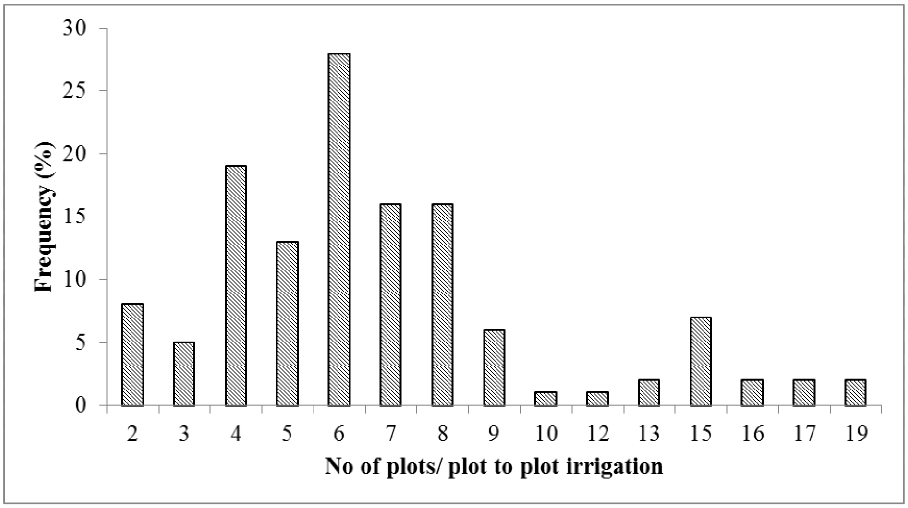


**Fig. 5. Number of plots variation with respect to the MC from RC and LC**

**Land size distribution in the area**

A total of 891 individual field plots belong to 128 farmers are found in the command area. Around 56% of the farmer fields were less than 0.4 ha in size (Fig. 4). Individual plot size ranged from 0.004 to 0.08 ha.It was reported during the focus group discussion that the total number of farmers in the *Bayawa* irrigation system was 50 with a larger plot sizes and more than 0.81 ha field, individually. Under this situation, more than 80% farmers had accessibility to a canal. According to secondary data, land fragmentation over the years has led to increase number of farmer fields and decrease individual plot size resulting a low accessibility of individual field plots to canal water. This is one of the critical factors to be considered in recommendation of OFC cultivation.

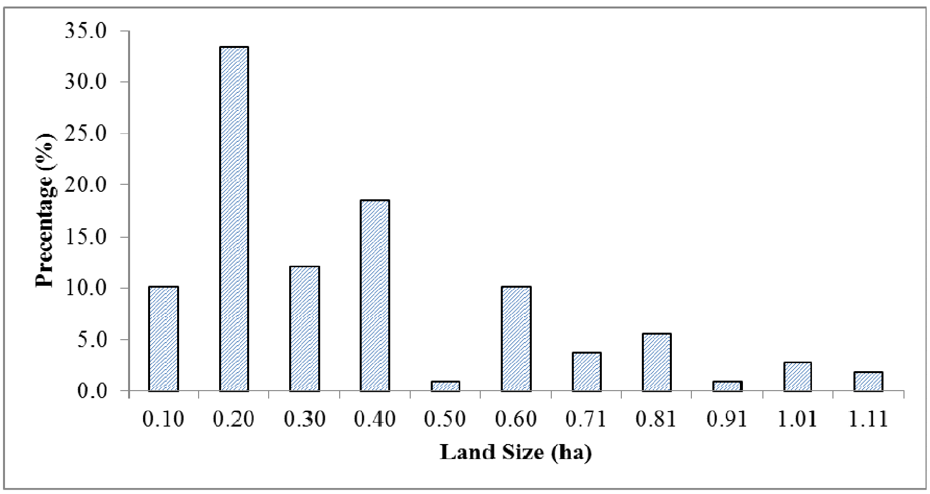


**Fig. 6. Individual farmer's land size distribution in the command area**

## CONCLUSIONS

Based on the ratio between the catchment area andthe tank water spread area (13.02), the *Bayawa* minor irrigation system is sustainable. Cross sectional areas of irrigation canals are highly variable along the distance from the head end to the tail end. Thus, it requires a large amount of irrigation water to maintain the required hydraulichead in irrigation canals. Large number of small plot sizes (0.004-0.08 ha) and their orientation restrict access to irrigation water and remove drainage water from respective fields. In addition, lack of systematic drainage canals are one of the major constraints for draining excess water for OFC cultivation particularly in high rainy seasons and in tail end of the command area. Hence, canal system layout and their effectiveness during both irrigation and drainage has to be considered in promotion of OFC for sustainable farming in MTs.

## ACKNOWLEDGMENTS

This work was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada.

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