

On-farm irrigation development and management in lower Myanmar: factors for sustainable rice production and collective action

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journal or publication title	Paddy and Water Environment
volume	11
number	1-4
page range	455-462
year	2013-01
権利	The final publication is available at Springer via http://dx.doi.org/10.1007/s10333-012-0336-0
URL	http://hdl.handle.net/10466/15479

doi: 10.1007/s10333-012-0336-0

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3 **On-farm Irrigation Development and Management in Lower Myanmar**
4 **-Factors for Sustainable Rice Production and Collective Action-**
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14 **Abstract**
15

16 The case study is aimed at assessing impacts of on-farm level irrigation development and
17 management on dry season rice production in the main irrigated rice production area of Myanmar.
18 The study was carried out from 2003 to 2009 in the middle reaches of the Ngameoeyeik irrigation
19 area of 28,000 ha. In addition to collecting information on water management and institutional
20 arrangement of the study area, hydrological and agronomic parameters were monitored during the
21 study period

22 Results showed the effectiveness of on-farm level infrastructural development for increasing rice
23 productivity owing to increased amount of water delivery, increased flexibility of water distribution,
24 and improved drainage conditions. Besides, encouraging the involvement of farmers in design and
25 implementation of the development led to improved farmer participation in the operation and
26 maintenance of the irrigation system. The outcomes of this study demonstrated the importance of
27 balancing between infrastructural and institutional development in irrigation systems of Southeast
28 Asia. Such infrastructural development should be in close association with institutional development
29 and capacity building, and the interactions between those two aspects should be well understood.
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34 **Keywords:**

35 Paddy rice production, Irrigation development, Participatory water management, Myanmar
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1 **Introduction**

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3 Agricultural sectors in a number of Asian countries still have the center role in improving their rural
4 economies. It is particularly important to increase and stabilize agricultural production by improving
5 irrigation and drainage systems and management (Taniyama, 2009). Many countries have
6 emphasized the need to adopt participatory irrigation management (PIM) with the formation of
7 farmer/water user organizations that may be combined with the development of affordable and
8 sustainable infrastructures suited to local situations. Outcomes of this effort are mixed, some are
9 successful but there seems to be more cases of failure.

10 There was a general consensus that large public irrigation systems in South and Southeast Asia
11 had not lived up to expectations with the main issues being institutions and design (Barker and Molle
12 2004). Public irrigation systems had grown faster than the institutions that were needed to regulate
13 them, while governments had tried to build irrigation from the top down approach. Bureaucracies
14 with little accountability to farmers and no incentive to improve management were empowered with
15 the mode and timing of water distribution (Barker and Molle 2004). Therefore, the norms of
16 cooperative behavior, community organization, and sense of community ownership that
17 accompanied successful communal irrigation systems had difficulties in evolving.

18 Myanmar is a country in Asia that relies its economy heavily on the agricultural sector. It
19 accounted for 32% of the country's GDP in 2009-2010: 17.5% of total export earnings and employs
20 61% of the labor force (Department of Agricultural Planning 2011). The Myanmar government's
21 goal is to promote increased production of paddy rice as it is the most important agricultural product
22 to ensure food security and to generate export revenues (Fujita and Okamoto 2000). For paddy, the
23 primary input besides land, is water. In Myanmar, 90% of harnessed water is used for agriculture.

24 A key priority within the agricultural water sector is the more efficient use of water through
25 on-farm improvement and water management training (Groenfeldt 2006). Myanmar's rice
26 production has steadily increased, especially after the introduction of high yielding varieties (HYVs)
27 in the late 1970s. The development of irrigation infrastructure encouraging dry season irrigated
28 rice production started in the early 1990s. Additionally, the Ministry of Agriculture and Irrigation
29 implemented 217 irrigation projects during 1988 and 2008 (Myo Zaw Zaw 2010). Consequently,
30 irrigated area in Myanmar increased from 1.00 million ha in 1987-1988 to 2.33 million ha in
31 2009-2010, and the average rice yield increased from 3.06 t/ha in 1996-1997 to 4.06 t/ha in
32 2009-2010 (Department of Agricultural Planning 2011), which is close to Asia's average rice yield.
33 However, large local variations in yields have been recognized.

34 Increasing productivity in irrigated agriculture can be achieved when both hard (e.g.
35 infrastructure) and soft (e.g. institution, farmer organization) aspects are in place but normally the
36 former governs the latter (Hirashima 1984) at the early stage of development. For example,

1 Sawada and Shinkai (2005) showed the relevance of poverty to the level of irrigation infrastructural
2 development. On the other hand, many past studies in irrigation management have not explicitly
3 tried to identify infrastructural circumstances that utilize the capacity of farmers and institutional
4 arrangements, especially at the on-farm level.

5 Based on the case study conducted in collaboration with the Irrigation Technology Center (ITC) of
6 the Irrigation Department (ID) of Myanmar, the objectives of this paper are to: 1) identify situations
7 and constraints of irrigation management in the rice production area of Myanmar; 2) identify and
8 quantify how on-farm level infrastructural development affects rice production in the case of lower
9 Myanmar; and 3) describe how farmers coped with the given infrastructural settings to improve
10 production. While part of the outcomes of this study have already been reported in several
11 publications (Matsuno and Horino 2007, Horino et al. 2007, Matsuno and Horino 2009), this paper is
12 reorganized to emphasize the important components of the study outcomes and includes additional
13 analysis and discussions following the previous publications.

16 **Materials and Method**

18 *Description of study area*

20 The entire study was carried out in the dry seasons of 2003 to 2009 in the middle reaches of the
21 Ngameoeyeik irrigation area located in the lower delta of Myanmar, which is the main rice
22 production area of the country.

23 The Ngamoeyeik irrigation area extends over 28,000 ha below the Ngamoeyeik Dam constructed
24 in 1995 (Figure 1). Double rice cropping is commonly practiced in this area in the dry season
25 (December to May) while some farmers grow upland crops. Owing to adequate rainfall, all farmers
26 grow rice in the wet season (June to October), while irrigation water from the system is mainly used
27 in the dry season.



Fig.1 Ngamoeyeik irrigation area in lower Myanmar

The study area is categorized into three different levels of development:

1) Intensive Area: Applying a Japanese standard land development method, the land in this area was separately consolidated with straight water courses (WC: farm ditches) and drainage canals. Each plot is around 40a. It was developed during the implementation of the collaborative project between the Japan International Cooperation Agency (JICA) and the Myanmar government. This area is a total of 15 ha and has 9 farm households;

2) Extensive Area: This area has been developed with different WC densities to study the appropriate WC density in Myanmar. The area is 48 ha with 38 farm households, where plot-to-plot irrigation is practiced. The plots are of various sizes, with an average of around 15 a; and

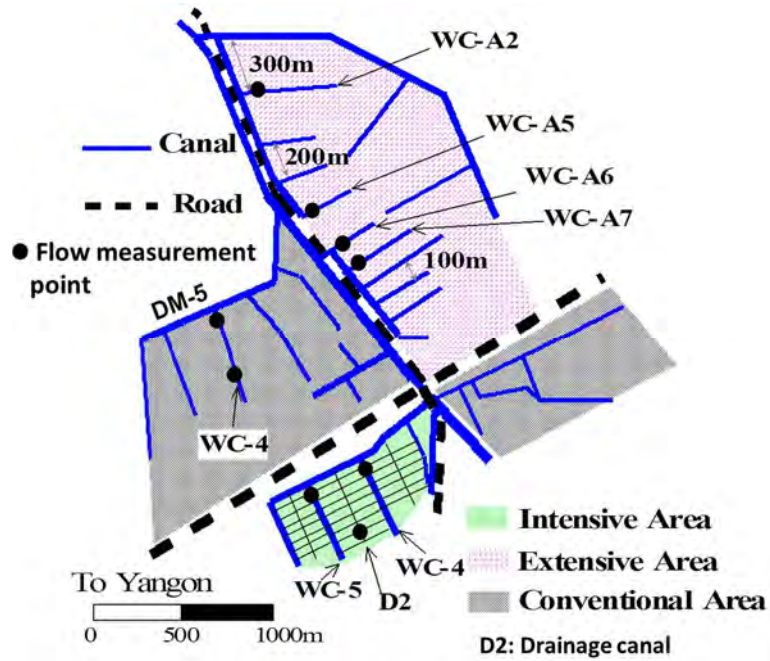
3) Conventional Area; Myanmar's standard water course layout with low irrigation intensity. WCs and farm ditches are partially developed. The total area is 45 ha. The average plot size is the same as in the Extensive Area.

The study area is located along the upstream of the main irrigation canal that has a relatively stable water supply compared to the downstream area. Irrigation water in the dry season is diverted from the main canal via the secondary canal and then to WCs. The secondary canal is the so-called Direct Minor (DM) in this study. All canals are earthen open-channel with trapezoidal cross section. The bed width of the main canal is 15 m on average with the maximum water conveyance capacity of 18 m²/s. The bed widths of secondary canals are around 1.5 m, while those of WCs are 0.3-0.6 m.

Most paddy fields are supplied with water from the WCs in the Intensive Area. In the Extensive and Conventional Areas, the paddy fields are essentially supplied with plot-to-plot irrigation, except for the paddy fields adjacent to WCs. Figure 2 shows the locations of the Intensive, Extensive, and

1 Conventional Areas.

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5 Fig 2. Schematic of the study area showing the three Areas

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8 *Field study*

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10 To quantify and compare the development status and water use efficiencies among the three areas,
11 information on hydrology, rice productivity and socio-economy were obtained. In addition, in
12 discussions with farmers and local government staff, the study tried to identify critical issues and
13 feasible measures in on-farm development for sustainable water use and farm management.

14 The study commenced with a field survey to collect information on land ownership, land use and
15 land elevation of the area. Other information, such as on-farm water management practices, cropping
16 calendar, agronomical inputs and outputs were obtained from interviews with farmers in the area.
17 The daily flow rate of the main water course of the three sub areas was observed in the dry season by
18 installing Parshall flumes coupled with automatic water level recorders. To estimate
19 evapotranspiration, data on meteorological parameters (e.g. precipitation, ambient temperature, and
20 solar radiation) were obtained from weather stations nearby to the area.

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1 **Result and Discussion**

3 *Institutional setting for water distribution*

5 Irrigation development in Myanmar started as early as the middle ninth century (Hatcho et al. 2010)
6 during the period the Burma tribe migrated into and conquered Pyu and other tribes and established
7 the Pagan kingdom in the middle reaches of the Irrawaddy River. Large-scale irrigation thrived with
8 the introduction of canal irrigation systems that allowed for the large-scale and stable withdrawal of
9 water and intensive production of rice.

10 Modern irrigation development of the country, similar to most Asian countries, accelerated after
11 the 1980s. Construction, operation and maintenance of the main structures up to the secondary canal
12 level of the irrigation schemes are the responsibility of the central government (Irrigation
13 Department: ID, Ministry of Agriculture and Irrigation of Myanmar). The construction and
14 management of the tertiary or WC canal and its lower levels are the responsibility of the farmers.

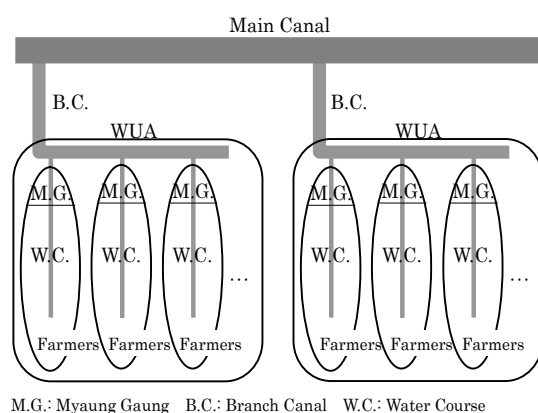
15 In the study area, the infrastructural development of tertiary and lower level canals is planned,
16 designed, and then implemented by ID with labor contributed by beneficial farmers. However, this
17 arrangement for development is not the same for most irrigated areas of the country, and, in many
18 cases, farmers are fully responsible for the development of the on-farm level infrastructures.

19 In the Ngamoeyeik area, only rain-fed paddy rice cultivation was practiced in the rainy season
20 before the Ngamoeyeik Dam came into operation in 1995. Therefore, it has a relatively short history
21 of farmers cultivating dry season irrigated paddy rice. Farmers in the study area still do not have
22 sufficient experience in collectively maintaining and managing WCs and the organization for
23 irrigation is still in the developmental stage.

24 Collective water users' organizations based on individual WCs have been recently developed,
25 particularly in Upper Myanmar in mostly arid and semi-arid areas (Myo Zaw Zaw 2010). Similarly,
26 in the Ngamoeyeik area Water Users' Associations (WUA), such as those illustrated in Figure 3, are
27 considered as the basic unit of the farmers' organization. Groups of farmers, referred to as Water
28 Users' Group (WUG), are in charge of irrigating their paddy fields from a single WC. The leaders of
29 these groups are locally called "Myaung Gaung," meaning water course head. Generally, WCs are
30 equivalent to tertiary canals, and the canals above these are Branch Canals (secondary canals: called
31 as Direct Minor in the study area) that are diverted from the Main Canal (primary canal). Normally,
32 WUAs are formed in units of these Branch Canals, and their leader is often the Myaung Gaung of
33 one of the WUGs among the WUA.

34 Myaung Gaungs are not government employees. Their status allows them to be exempt from
35 mandatory labor service for the maintenance of WCs and to receive priority water supply, among
36 other privileges. The main role of a Myaung Gaung is to oversee the repair, cleaning and other

1 required work for the O&M of WCs, and, should a problem arise, report same to the ID's canal
2 inspector.



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Fig. 3 Organizational structure of irrigation management in Myanmar
(Source: Matsuno and Horino 2007)

7 Despite these institutional arrangements, no substantial activities by the WUAs have been
8 observed in the Conventional Area in the past. Water diversion from the main canal to the secondary
9 canals (DM-5 in the case of the Conventional Area) is carried out by the gate operators from the ID
10 Maintenance Office, and farmers are not involved in this operation. For DM-5, the gate operation is
11 not conducted frequently and is virtually left open at a fixed level. The main task of the gate operator
12 is therefore to make regular visits for inspection.

13 At the irrigation system level, Water Distribution Committees (WDCs) were established to
14 organize and be responsible for supplying irrigation water (on the water allocation management side).
15 The WDC in the Ngamoeyeik area is chaired by the Chairman of the Township Peace and
16 Development Council (Township chairman: TC), and consists of representatives from the Myanmar
17 Agricultural Service (MAS), the Settlement and Land Records Department (SLRD), the Agricultural
18 Mechanization Department (AMD), and ID engineers. Of the three townships in the Ngamoeyeik
19 area, Hlegu Township has the largest population, and its chairman is also the Chairman of the WDC.

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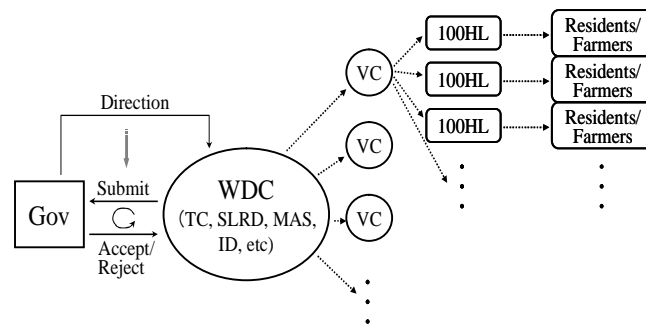
21 *Water allocation Rule*

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23 Although the WDC of the study area does not have a long history and is still at the developmental
24 stage, it functions as the decision making body for most water allocation plans that target the
25 paddy fields that have not started dry-season rice cultivation. Figure 4 illustrates the general
26 procedure followed by the water allocation plan. Firstly, each government divisional office inquires
27 from the WDC about the allocation plans for the area to be planted during the relevant period. The

1 WDC in response considers the usable amount of water (the amount of available water resources)
 2 and the condition of the land (location, elevation, etc.), and then replies to the government on the
 3 areas that could be irrigated. If the government approves the plan, the amount of water to be
 4 allocated is decided on in accordance with the area to be benefited. The result of the decision is then
 5 passed on from the WDC to the VCs (village track chairmen) and from the VCs to the 100 HLs
 6 (100-household leaders: The 100 HL is a representative of the group that consists of about 100
 7 households and is similar to a mutual support group). Each 100 HL then informs the farmers, who
 8 are also members of WUA, in his/her jurisdiction of the results. The request from the WDC is not
 9 always approved by the government at once and several adjustments are normally required between
 10 the WDC and the government.

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14 Fig. 4 Schematic of the decision making process for water allocation

15 (Source: Matsuno and Horino 2007)

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17 *Rice production and physical constrain in the study area*

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19 The data and information obtained during the study confirmed distinguished differences among the
 20 three sub-areas as follows: Intensive area had a relatively high rice yield (average of 4.3 t/ha) with
 21 appropriate availability of irrigation water and sufficient drainage conditions; the Extensive area had
 22 a low yield (average of 2.0 t/ha) due to poor drainage, mainly caused by the undulation of plots; and
 23 the Conventional also had low yields, the same yield level as in the Extensive area due to severe
 24 water scarcity and micro-topography.

25 The Intensive area has an ease of water control owing to the straight alignment of irrigation (WC)
 26 and drainage canals along with land leveling that allows for water to be distributed to each plot
 27 directly from the water courses. On the other hand, even without a shortage of water, the Extensive
 28 area has problems in water distribution and drainage due to insufficient canal alignments and
 29 gradients that do not correspond to plot elevations. The Conventional area has a similar problem in

1 micro-topography, in addition to a restriction of intake to the water course. Owing to these physical
 2 conditions in the Extensive and Conventional areas, the water courses do not function properly and
 3 farmers have to rely heavily on plot-to-plot irrigation. As such, farmers are unable to distribute water
 4 to tail end plots efficiently even though sufficient water is available at the intakes of water courses.

5 Regarding the water intakes, the Intensive and Extensive areas have approximately 10mm/day
 6 available for distribution to water course. In this area, the estimated daily ET was 4.5 mm/day on
 7 average and deep percolation was 1.0-1.5mm/day (clayey soil). Therefore, from a water balance
 8 perspective, these two sub-areas do not have a water shortage. On the other hand, the Conventional
 9 area's water availability to the water course was 4.5 mm/day on average in the 2003-2004 and
 10 2004-2005 dry seasons. This result implies that the Conventional area may be facing water scarcity.
 11 Because of the water shortage and undulated plot formations, the irrigated area of the Conventional
 12 area is limited to the adjacent water course.

13 In summary, from the analyses of hydrological data, ground elevation and WC alignment, and the
 14 results of farmers' questionnaires, the present status of each area is shown in Table 1.

15
 16 Table 1 Summary of study area characteristics in 2003-2004 and 2004-2005 dry seasons

Area	Infrastructural development level	Average rice yield (std)	Notable situation	Monitored water course and beneficially
Intensive	High (Land consolidated: Land leveled, separation of irrigation and drainage canals)	High: 4.32 t/ha (0.77)	Sufficient water supply	WC-4 and WC-5
Extensive	Moderate (Increased canal densities)	Low: 2.22 t/ha (0.28)	Poor drainage, land elevation problem	WC-A2, WC-A5, and WC-A7
Conventional (DM-5)	Ordinal (Traditional style of development)	Low: 1.92 t/ha (0.68)	Problem in water delivery	WC-4

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 19 *Factors affecting rice yield in dry season*

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 21 The previous section described the physical limitations of the Extensive and Conventional areas that
 22 might be significantly affecting the rice productivity in the irrigated agriculture of the area.
 23 Obviously, there also are other agronomical factors affecting the yield. In order to quantify the

1 significance of such factors, a multiple regression analysis was carried out. For the analysis, the level
 2 of infrastructural development (e.g. Conventional, Extensive, and Intensive), the amount of fertilizer
 3 applied, and rice varieties are considered as independent variables, and rice yield was set as the
 4 dependent variable. The other potential factors, such as metrological conditions, soil, labor input,
 5 and pesticide application did not differ among the three sub-areas and they were not considered for
 6 the dependent variables. The categorical regression analysis with the optimum scaling method was
 7 applied using data from the 2003-2004 and 2004-2005 dry seasons. The result is shown Table 2.

11 Table 2 Results of categorical regression analysis on effect of infrastructural development,
 12 fertilizer input, and variety on rice yield ¹⁾

Independent Variable	Range	Coefficient of standardization	Level of Importance ²⁾
Infrastructural development level	1~3 ³⁾	0.865** ⁴⁾	0.879
Fertilizer input	70~490 kg/ha ⁵⁾	0.174* ⁴⁾	0.105
Rice variety	1~8 ⁶⁾	0.288**	0.016
R ²		0.836**	

15 Note :

16 1) Source : Matsuno and Horino (2009)

17 2) Calculated by the equation : (Coefficient of standardization*Zero-order correlation)=Coefficient of determination.

18 3) 1. Conventional area, 2. Extensive area, 3. Intensive area.

19 4) Significant at 1%(**) and 5% (*).

20 5) The optimized scaling method was used to categorize the fertilizer input level.

21 6) The farmers in the study area used 8 types of nonphotosensitive highyield variety for dry season rice cultivation.

23 The result shows that all the independent variables are significantly correlated with the yield.
 24 Among them, the land development level is identified as the most important factor. This implies that
 25 the impact of agronomical improvement, such as increasing fertilizer application and using the high
 26 yield variety on the field, is minimal without improving the physical condition of irrigation and
 27 drainage.

29 *Collective Action for irrigated rice production*

31 Prior to the 2005-2006 dry season, the study team organized a total of four workshops with the
 32 participation of all farmers (except one workshop with absence of few farmers) of the Conventional
 33 area to report its findings and discuss possibilities of improving water management for rice

1 production in the area. A plan of action was aimed at increasing rice production by increasing the
2 amount and flexibility of water intake to the water course for ease of water control and delivery to
3 the fields. Through this process it was also intended to reach common understanding among farmers
4 on the current constraints and increase awareness on participatory operation and maintenance for
5 water management.

6 The farmers in the Conventional Area in WC-4 perceived that water scarcity was the most critical
7 issue for rice production as expected and were very positive about taking collective measures of
8 action. It was also confirmed and stated to all relevant farmers that, owing to the problem of
9 farm-plot elevation, water allocation would be impossible to some lands even with the change in WC
10 alignment, and that water could not be allocated to the entire area owing to limited available water.
11 Also, in order to improve the state of water intake from the WC, it was pointed out that the intake
12 capacity of the inlet at the secondary canal (DM-5) needed to be rehabilitated as the bed slope of the
13 DM was irregular and damaged in some places.

14 It was obviously important to develop proper WCs. Therefore, the potential to develop a new WC
15 alignment (WC layout), including quaternary or fourth-level canals, taking into account of the
16 existing topography and attributes such as landholders, was assessed. After discussion with farmers,
17 it was decided to adopt the following for the Conventional Area based on the general consensus of
18 the farmers: 1) the cost of rehabilitation should be low and it can be done by farmers providing
19 labor; 2) the existing farm-plot layout will be unchanged as much as possible; 3) although it is not
20 possible to deliver water to all farm-plots, the minimum number of plots traversed will be reduced
21 from the present number for farm-plots where water intake is possible; and 4) the existing WCs will
22 be rehabilitated and utilized effectively, and newly laid parts will be kept to a minimum.

23 Conversely, during these workshops, it was discovered that the majority of farmers in the
24 Extensive Area regarded the problem of poor drainage as more important than that of the WC
25 alignment, despite the fact that water delivery was impossible to some land due to farm-plot
26 elevation. It was therefore decided that the present alignment of the WCs should be retained.

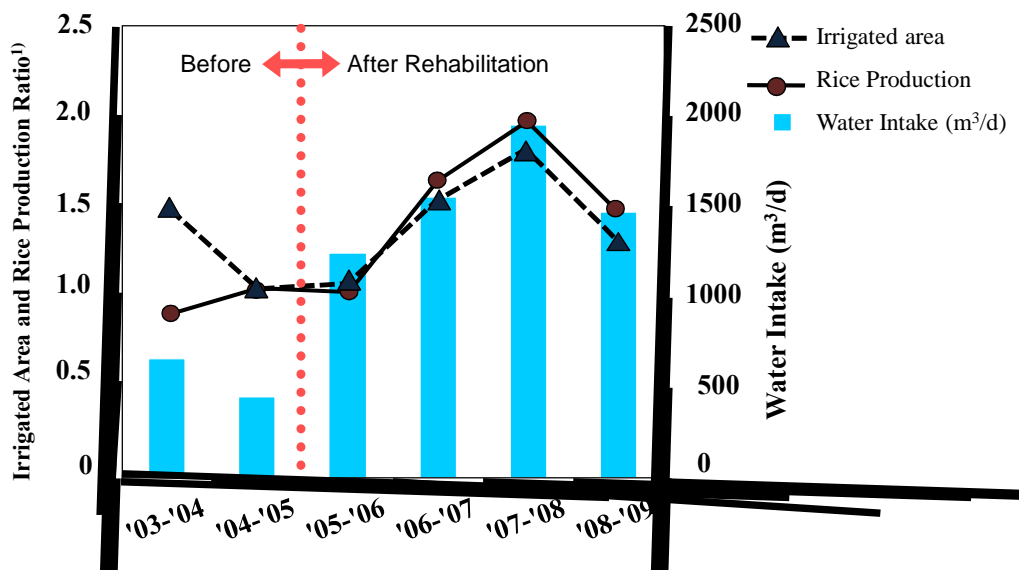
27 It was also decided that the rehabilitation of WC-4 and the DM-5 should be carried out by the
28 farmers themselves before the beginning of the 2005-06 dry season in December, with technical
29 guidance from the ITC for WC-4 and from the Maintenance Office of the Ngamoeyeik area for
30 DM-5. The largest change was that the inlet of WC-4 at DM-5, i.e. the upper-level secondary canal,
31 be placed in a slightly upstream position and the alignment of WC-4 changed to have more contact
32 with farm-plots with the WC.

34 *Consequence of intervention*

36 Figure 5 shows the changes in irrigated rice production area, rice production, and amount of water

1 intake in the Conventional area from the 2003-2004 to 2008-2009 dry seasons. After the intervention,
 2 the amount of water intake increased 2.8 times, and the irrigated area increased 1.5 times, in addition
 3 to an increased rice yield of 3.0 t/ha. The increase in the irrigated area was not proportional to the
 4 increase in the water intake because the existing plots were under water shortage before the
 5 intervention. Therefore, only surplus water was used for the newly irrigated plots and some plots
 6 still face difficulty in water distribution due to land elevation even after the new alignment. Overall,
 7 most farmers felt improved reliability of water delivery and flexibility of water management with the
 8 new alignment, especially the downstream farmers who benefitted from the increased flexibility.

9 Consequently, the operation and maintenance activity organized by the village chairman until the
 10 2006-2007 season, was organized by the farmers themselves from the 2007-2008 season. This
 11 implies that more commitment from farmers for water management in an organized manner was
 12 caused by the collective actions for improvement of the infrastructure, leading to a realization of the
 13 advantages of participation.



15 Note: 1) Values of irrigated area and rice production are relative ratios to those in the '04-'05 dry season.
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 18 Fig. 5 Changes in irrigated rice cultivation area, rice production, and amount of water intake in
 19 Conventional area from 2003-2004 to 2008- 2009 dry seasons
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21 In addition, we found that the number of plot pathways from WC to the plot of interest can be
 22 used as an indicator for flexibility of water management (Horino et al. 2007). In principle, the
 23 number of plot pathways should be reduced when more plots can take water directly from the water
 24 course. Contrarily, the number of plot pathways should increase when the irrigated area was
 25 expanded. Therefore, our intervention should cause a set off in terms of the number of plot pathways.

1 In fact, only a slight decrease in the number of plot pathways was observed after the intervention
2 which did not affect the flexibility of water management.

3 4 *Direction of irrigation development and management*

5
6 An early stage of irrigation development in Asia after World War II can be typified by large scale
7 infrastructural development (Hirashima 1984). Kikuchi (2005) envisaged development paths of
8 irrigated agriculture in monsoon Asia in three stages. The first stage was an extensive expansion
9 phase coping with population growth and an abundance of uncultivated land. The second was the
10 phase of increasing productivity of the cultivated land by irrigation development. The third is to
11 further improve productivity of irrigated land by improving existing systems by rehabilitation,
12 modernization and improving management. In many cases, these stages were overlapping at some
13 point but shifted towards the third stage in accordance with relative costs for development. With an
14 increasing population and a decrease in arable land area as in the first stage, the cost of land
15 expansion would eventually become higher than the cost of irrigation development. When the
16 second stage progresses, the cost of irrigation development would increase as the focus of
17 development shifts to areas that require more cost to construct irrigation infrastructure with less
18 available water. In the third stage, there is evidence that the ratio of economic return varies in
19 irrigated areas because at this stage farmer participation in the project is an important factor for
20 success, but it often failed (Kikuchi, 2005). To ensure sustainable management and operation of
21 water control systems, understanding the need for a solid foundation with local participation and
22 management organization is essential (Hatcho, Ochi, and Matsuno, 2010). In applying this “stage
23 theory”, the present situation of Myanmar is considered to be at the transition stage, currently
24 somewhere in between the late second and third stages. On the other hand, the emphasis is currently
25 on the development of main hydrological infrastructures such as dams and main canals, and
26 sufficient resources are not committed to on-farm level development.

27 Based on the results of this study, there is a high possibility that introducing Japanese-style land
28 consolidation like the method applied in the Intensive Area would contribute to an improvement in
29 the productivity of paddy rice cultivation in Myanmar. As seen in the Mandalay area, there are
30 some pilot areas where land consolidation with separate irrigation and drainage canals have been
31 implemented. However, it is clear that expanding such Japanese-style land consolidation to the entire
32 country is difficult economically and technically. Presently, it is expected that most of the areas with
33 low productivity in the Myanmar delta area are employing similar methods as the Conventional Area.
34 The Extensive Area, which is considered as the intermediate method between the Intensive Area and
35 the Conventional Area, did not show a significant difference in productivity when compared to the
36 Conventional Area. This suggests that, in order to improve productivity, in addition to making a

1 change to the density of WCs other measures are also necessary.

2 In order to resolve these problems and, in particular, to expand the irrigation area and increase the
3 productivity in the Extensive and Conventional Areas by increasing the efficiency of water use for
4 paddy rice cultivation in the dry season, the following interventions could be considered: 1) Improve
5 farm-plot elevation with respect to the bed slope of WCs and ground level of the plots; 2) Construct
6 WCs adapted to the farm-plot gradient, enabling water to reach further downstream farm-plots and
7 install field ditches wherever necessary (leave the final decision to farmers); 3) Improve drainage
8 conditions, and make it possible for each farmer to drain water quickly whenever necessary; 4) Line
9 WCs to reduce seepage losses (to farm-plots unsuited for cultivation) and at the same time expand
10 the potential area of water conveyance; and 5) Enhance the institutional capacity of WUAs through
11 information provision, training, etc., and strengthen the efficiency of water use through rotation
12 within WCs, etc.

13 It is obvious that basic infrastructural developments, such as land leveling, would be essential,
14 which was consistent with the perception of farmers as was identified in the questionnaire. A realistic
15 response would probably be to establish provisional measures, and, in the meantime, to promote the
16 technology for preparing new equipment and supplies for construction technology in the long run.

17 PIM has not been widely practiced in Myanmar, and it seems to be a long way from developing a
18 bottom-up decision making process in the present circumstances. On the other hand, the officers of
19 the ID and the local managers have begun to recognize the importance of participatory management
20 that have resulted in a series of trainings and workshops conducted by the government and
21 international organizations. In order for the participatory management to be widely accepted in the
22 nation, the first step could be to develop the framework for a farmer-centered irrigation management
23 system, rights and duties of farmers, etc. that are adapted to the country's economic and social
24 circumstances.

27 **Conclusion**

29 This study revealed that the premise for a successful water management with farmers' participation
30 would go hand in hand with proper irrigation infrastructures that can be managed by farmers. It was
31 also revealed that farmers would consider maintaining the irrigation canals voluntarily when they
32 recognize the increase in water accessibility through the improvement of irrigation facilities and its
33 contribution to improving productivity. The government/donor may need to provide the information
34 and technologies in a timely manner for farmers to develop irrigation facilities and its management
35 by themselves.

36 The outcomes of this study emphasize the importance of balanced development between hardware

1 and software in Southeast Asia. The infrastructural development should go along with the
2 institutional development and capacity building, and the interactions between these two aspects
3 should not be ignored. In this process, the government or state agency has a large role to play by
4 supporting farmers and their organizations in capacity building to handle infrastructures in the
5 development.

6 7 8 **Acknowledgement**

9 The authors would like to express their sincere thanks to the Irrigation Technology Center of
10 Irrigation Department, Ministry of Agriculture and Irrigation, Union of Myanmar for their full
11 cooperation in conducting this study.

12 Part of the results of the study is based on the project outcomes conducted by the Japanese Institute
13 of Irrigation and Drainage (JIID). Part of the research activities were supported by the research grant
14 from the Japanese Society for the Promotion of Science.

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