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論 文 の 内 容 の 要 旨

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論文題目　Analysis of landscape level environmental variation and on-farm technological adoption for sustainable rice production in three rice ecosystems with contrasting water environments in Cambodia

(カンボジアの水環境の対照的な３つの稲作生態系での持続可能な稲作のための景観レベルの環境変異と農家の技術受容の解析)

Rice yield is generally low (2.7 t ha^{-1} in 2008) in Cambodia. Increase rice production remains the central focus of Cambodia’s agricultural policy for potential export for economic development and for livelihood improvement for rural population. Paddy rice is grown over diverse water environments in Cambodia; irrigation rehabilitation area of those constructed during Pol Pot time, deepwater rice ecosystem in flood plains of Tonle Sap Lake, rainfed lowland rice ecosystem sharing over 80% of Riceland in Cambodia . Rice yield should be increased in every rice ecosystem for food security and better livelihood for farmers. This study focused on (1) heterogeneous water environments within a village or within a landscape of human sight (i.e. defined as “micro-scale” in this thesis) within each of the rice ecosystems, (2) transfer and adoption of technologies available for farmers, and (3) positive externalities (i.e. multifunctional roles) of rice farming such as biodiversity conservation, landscape or cultural values, in order to improve rice yield in sustainable manner.

Analysis on the process of irrigation rehabilitation in Kamping Puoy in Battambang province, Northwest Cambodia, in the consecutive 4 cropping seasons from 2008 wet season rice (WSR) to 2010 dry season rice (DSR) revealed standing water depth (e.g. from September to November) much deeper in downstream fields than in upstream fields along the transect of the secondary drainage canals in WSR; farmers adapted to plant medium and late maturing varieties (maturity time in December and January) in the former while early and early medium maturing varieties (maturity time in November) in the latter. Water conditions were less different between upstream and downstream fields in DSR and with more uniform planting and harvesting time. As the area percentage of fields where DSR was introduced increased from 2008 (54%) to 2010 (100%), planting time in WSR shifted later (e.g., from May to July) with declining proportion of dry seeding method and mid-season tillage. On-farm grain yields in DSR were low (287 and 247 g m^{-2} in 2009 and 2010 on average, respectively), partly due to insufficient weed control and small amounts of fertilizers. Yields were lowest in fields which practiced DSR for the first time, and some improper management practices (such as variety mis-choice, wrong use of insecticides instead of fungicide) were observed, indicating insufficient agriculture extension support to farmers. Grain yield in WSR (286 and 291 g m^{-2} in 2008 and 2009 respectively) could be increased by transplanting, use of high yielding Raing Chey variety, and application of higher amount of N inorganic fertilizer.

Characterization of DWR area in the flood plain of Tonle Sap Lake in Northwest Cambodia along a transect of water depth gradient (from the shallower rainfed lowlands side to the deeper floating rice side) during wet season rice (WSR) production in 2008, 2009 and 2010 revealed (A) very gentle and almost flat slope (only 40 cm elevation differences in 1 km distance) and 3 groups of rice zones with (1) upper fields located closer to the National Road Number 5 where water depth was shallower and only lowland rice (LR) was grown; (2) middle fields where both LR and floating rice (FR) were grown and where lowest grain yield was recorded in 2009 due to the flood; and (3) lower fields located near to the Lake where water depth was deeper (average maximum depth more than 150 cm) and only FR was grown. (B) Secondly it was also revealed large yearly differences in flood from Tonle Sap Lake; 2008 and 2009 when water came to the paddy fields from both the inundation from Tonle Sap Lake and rainfall and when the presence of continuous standing water started in September, reached maximum in

October (> 1 m) and became non-flooded conditions in early December vs. 2010 when flood did not come from the Lake and all the 3 rice zones had less than 30 cm of maximum water depth and when rainfed lowland rice attained higher yield due to higher N fertilizer application rate. The overall average grain yield for both years of 2009 and 2010 was low with only 1.1 t ha^{-1} for FR and 1.8 t ha^{-1} for LR. Late sowing and/or lack of basal N fertilizer application resulted in smaller plant stands when flood occurred, resulting in greater flood damage and more crop failure. Limited forecasting ability for water availability (e.g., flood occurrence) for the subsequent cropping season leave large risks for deep water rice production in flood plains of Tonle Sap Lake.

The study showed that grain yield was very low (1.5 t ha^{-1}) in the studied area in RFLR in Kompong Chhnang province because farmers planted only local varieties on poor soil fertility with the low rate of inorganic fertilizer (14 kg ha^{-1}). Results of on-station experiments in WSR 2009 and 2010 showed that yield was improved by planting improved variety (e.g. Phka Rumdoul) and applying the recommended amount of fertilizer. Yield of Phka Rumduol with fertilizer application could be 60% higher than that of Thmar-Ror-meal (local variety) with fertilizer and more than triple that of Thmar-Ror-meal without fertilizer in WSR 2009. However the efficient level of improved variety and fertilizer was less in WSR 2010 because of water deficit. Adoption level of improved variety and fertilizer depends on the availability and popularity of these resources among the farmers. Farmers preferred to grow Phka Rumduol in WSR 2010 but the adopted area was not high due to the seed shortage. On the other hand, fertilizer was not highly adopted by farmers in WSR 2010 due to unavailability of fertilizer (lack of money to purchase) and farmers' concerns on low benefit return in the drought situation.

Multifunctionalities of the 3 rice ecosystems (IR, DWR and RFLR) in Cambodia were recognized, such as those categorized as (1) livelihood and economic, (2) environment, and (3) social and cultural, at least in local scale among villagers, although the value of each function has not been quantitatively estimated. Bio-resources from paddy fields are important to farmers' livelihood, particularly poor people.

This study shows that (1) water environments are different not only between the rice ecosystems but also within each of the rice ecosystems at micro-scale i.e. between upstream and downstream fields along secondary canals in irrigated rice ecosystem, transect from rainfed lowland side towards the lake in deep water rice ecosystem in flood plains of Tonle Sap Lake, toposequential differences within a village in rainfed lowland ecosystem. The micro-scale variation in water conditions has large influences on farming practices and yield, so the characterization of field water environments is important for technology development and dissemination; (2) insufficient and ineffective usage of agricultural resources (e.g., inorganic N fertilizer, herbicides, fungicides, photoperiod sensitive variety) caused lower farm level yield than possible attainable level in all the 3 rice ecosystems in Cambodia. In rainfed lowland ecosystem while an improved variety of Phka Rumduol was rapidly and popularly adopted by farmers but in short of seeds multiplication, adoption of sufficient amount of inorganic fertilizer was hindered by water deficit and influenced by the cost-benefit balance; and (3) multifunctionlaities of rice production were recognized at village or landscape levels such as other biological resources for livelihood, should be up-scaled in order to draw attention of policy makers to attain sustainable rice farming in Cambodia.