Provision of ecosystem services by paddy fields as surrogates of natural wetlands

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This paper reviews research on the ecosystem services or multifunctionality of paddy rice cultivation in Japan, with the aim of describing the current status of the subject and exploring options for introduction of sustainable practices. In the past, numerous studies have been conducted in Japan and other rice producing countries to identify, estimate, and value the multiple outputs from paddy rice cultivation (Matsuno *et al*. 2006).

Most rice is produced in paddy fields in Japan. People have cultivated rice for about 3000 years in Japan. Paddy field occupies 25,000 km^2 (2009) in Japan. This is far bigger than the area of wetland, 820km^2 (1999). However, 3,800 km^2 of former paddy field is now not cultivated due to reduced consumption of rice. Paddy fields in Japan have also changed qualitatively. Satoyama, a traditional socio-ecological production landscape, which provided a functional linkage between paddy fields and the associate environment has lost function as traditional lifestyles and practices have changed.

Ecosystem services provided by paddy fields include the following; groundwater recharge, production of non-rice foods, flood control, soil erosion and landslide prevention, climate-change mitigation, water purification, culture and landscape, and support of ecosystems and biodiversity.

Rice-fish farming is practiced in many countries in the world, particularly in Asia (Halwart and Gupta 2004). Although it is not a major system in Japan, carp and crucian carp are produced in paddy fields. *Nigorobuna* carp, an endemic species from Lake Biwa is important resource to make local fermented sushi, “Funazushi”. A large female fish is sold fo 5,000 yen. The yield of the *Nigorobuna* fishery has been decreased through degradation of spawning sites along the lakeshore. This fish also spawns in paddy fields during the flooding period. However modernization of irrigation system now prevents the fish from running into the paddy from river. Shiga Prefecture implemented a project for direct environmental payments of 3,500 yen per 1,000 square meters to groups that engage in water management and maintenance of the fishways required for fish to run up the river to spawn.

Paddy is an important part of water recycling system in the basin. The recharge in the paddy field in the middle Shira River Basin was estimated to be about half of the intake water from the Shira River in Kumamoto area (Tanaka *et al.* 2010). The reduction of the cropping area led to a reduction in groundwater recharge from 3.0 x 10^8 m^3 (267 km^2) in 1970's to 1.5 x 10^8 m^3 in 2008. This is about 25% of the annual recharge of this area in 2007 (6.00 x 10^8 m^3/year). Ground water levels were 0.5-1 m higher and the ground water storage 20% larger during the irrigation period in an alluvial plain (Anan *et al.* 2006).

Paddy fields can act as flood control basins. For example, maintaining levees at 25cm height can restore this function in the abandoned paddy (3,800 km^2), providing a reservoir of 4,900 m^3 (http://www.jiid.or.jp/works/jishu/pdf/ 01.pdf). Ichikawa City pays the owners of lowland paddy fields to conserve the fields for flood control. The Paddy Field Dam project is tested in Niigata Prefecture (Yoshikawa *et al.* 2010).

Runoff from paddy is regulated by runoff control devices when the water inflow from the paddy field to the drainage device exceeds the outflow capacity. The result of simulation studies shows the discharge in the main channel could be decreased by 26% using these practices. Prevention of soil erosion from paddy fields is estimated to be 0.83 t/ha/y in steep land with slopes greater than 1:20 in Okayama Prefecture. Several authors have reported that paddy fields remove nitrogen from water (Maruyama *et al*. 2008). Nitrogen removal depends on the concentration in the inflow water, with Tabuchi (1998) reporting net losses when the inflow rose to 2–3 mg N/L or greater.

Paddy fields have provided a subject for Japanese culture. Asahi Shimbun Newspaper Company selected the Top 100 Japanese Rural Landscapes among 3,024 nominated sites by the public survey in 2008. Keywords that appeared frequently in the nominations showed that *Furusato* (Home) was associated with paddy field (Iwata et al. 2011). Terrace paddy, in particular, attracts people. For example an art festival held in the terrace paddy of Echigo-tsumari drew 37,000 visitors in 2010.

More than 5,000 species are found in paddy fields and associated environments such as irrigation ditch. Many of the species, such as red dragonfly and killifish are familiar in daily life. However the number of species and abundance has decreased due to three causes: land consolidation and modernization of irrigation system, abandonment of cultivation, and use of agri-chemicals. Several species have become endangered. Some measures are used for conservation of biodiversity in paddy fields. Symbolic species are used as a target for biodiversity-conscious agriculture. Oriental white stork and crested ibis were extinct in the wild. Both species were breed in captivity in Toyooka City and Sado City. These cities launched release programs and promoted agriculture-oriented projects to restore their habitats. Agri-environment schemes and agriculture and biodiversity certification accompany these programs (http://www.biodic.go.jp/biodiversity/shiraberu/policy/pes/en/index.html). Toyooka City encouraged farmers to apply “white stork-friendly farming methods” in which farmers are required to reduce pesticide use by 75 percent, if not entirely, and to flood their paddies deeper and for a longer period of time than for conventional farming methods. This allows tadpoles time to develop into frogs, etc. Toyooka City pays farmers who adopt this method and certifies the flying-stork brand. Rice with this brand can be sold at higher price than ordinary rice. These efforts encourage eco-tourism, with about 400,000 visitors each year visiting the Eco-Museum Center for Oriental White Stork in Toyooka City.

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