Integrated Farming System - An Ecofriendly Approach for Sustainable Agricultural Environment – A Review

By

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Research Article

Integrated Farming System - An Ecofriendly Approach for Sustainable Agricultural Environment – A Review

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ABSTRACT

Sustainable development in agriculture must include integrated farming system (IFS) with efficient soil, water crop and pest management practices, which are environmentally friendly and cost effective. In IFS, the waste of one enterprise becomes the input of another for making better use of resources. In integrated crop livestock farming system, crop residues can be used for animal feed, while manure from livestock can enhance agricultural productivity. IFS also play an important role in improving the soil health by increasing the nitrogen, phosphorous, organic carbon and microbial count of soil and thus, reduces the use of chemical fertilizers. Moreover, IFS components are known to control the weed and regarded as an important element of integrated pest management and thus minimizes the use of weed killers as well as pesticides and thus protects the environment. The water use efficiency and water quality of IFS was better than conventional system.

Keywords: IFS, Environment, Soil health, weed control, pest control.

INTRODUCTION

The concept of sustainability is an important element in the development of integrated systems. The MEA (2005) defined it as a characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generation or population in other locations to meet their needs. Developing countries around the world are promoting sustainable development through sustainable agricultural practices which will help them in addressing socioeconomic as well as environmental issues simultaneously. Within the broad concept of sustainable agriculture “Integrated Farming Systems (IFS)” hold special position as in this system nothing is wasted, the byproduct of one system becomes the input for other. Sustainable development in agriculture must include integrated farming system with efficient soil, water crop and pest management practices, which are environmentally friendly and cost effective. Integrated farming system are often less risky, if managed efficiently, they benefit from synergisms among enterprises, diversity produce environmental soundness (Lightfoot, 1990). Moreover, based on the principle of enhancing natural biological processes above and below the ground, the integrated system is the combination that reduces erosion, increases crop yields, soil biological activity and nutrient recycling, helps in efficient use of water, reduces pest and diseases, intensifies land use, improving profits and can therefore help reduce poverty and malnutrition and strengthen environmental sustainability.

INTEGRATED CROP LIVESTOCK FARMING SYSTEM

An integrated farming system consists of a range of resource-saving practices that aim to achieve acceptable profits and high and sustained production levels, while minimizing the negative effects of intensive farming and preserving the environment (Lal and Miller, 1990; Gupta et al., 2012). Within this framework, an integrated crop-livestock farming system represents a key solution for enhancing livestock production and safeguarding the environment through prudent and efficient resource use. In integrated crop livestock farming system the waste of one enterprise becomes the input of another for making better use of resources (Tiwari, 1993). For example, crop residues can be used for animal feed, while manure from livestock can enhance agricultural productivity by intensifying nutrients that improve soil fertility as well as reducing the use of chemical fertilizers (Gupta et al., 2012).

For agricultural use animal excreta can be used for fertilizer, feed and fuel. Excreta have two crucial roles in the overall sustainability of the system:
1. Improving nutrient cycling

Excreta contain several nutrients (including nitrogen, phosphorus and potassium) and organic matter, which are important for maintaining the soil structure and fertility. Animal excreta contains the major inorganic nutrient components (N, P and K) (Table 1).

Table 1: Typical values for the nutrient content of manure sampled in Virginia. Values are in pounds of nutrient/ton except where noted for liquid sources.

<table>
<thead>
<tr>
<th>Manure</th>
<th>Total Nutrient Content (pounds/ton or pounds/1000 gallons)†</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nitrogen</td>
</tr>
<tr>
<td>Dry Broiler Litter</td>
<td>62.58</td>
</tr>
<tr>
<td>Dry Turkey Litter</td>
<td>61.75</td>
</tr>
<tr>
<td>Layer or Breeder</td>
<td>36.46</td>
</tr>
<tr>
<td>Liquid Dairy*</td>
<td>22.61</td>
</tr>
<tr>
<td>Semi-Solid Dairy</td>
<td>10.54</td>
</tr>
<tr>
<td>Semi-Solid Beef</td>
<td>12.79</td>
</tr>
<tr>
<td>Swine Lagoon*</td>
<td>10.14</td>
</tr>
<tr>
<td>Mixed Swine*</td>
<td>41.13</td>
</tr>
</tbody>
</table>

* Values are in pounds/1000 gallons. All other values are in pounds/ton.

Source: Mullins 2009

2. Providing energy

Excreta can be dried, composted, or liquid-composted for the production of biogas and energy for household use (e.g. cooking, lightning) or for rural industries (e.g. powering mills and water pumps). Fuel in the form of biogas or dung cakes can replace charcoal and wood. It can be methane-fermented, directly combusted, or made into solid fuel.

Furthermore, biomass production of feed is possible; the excreta is treated to be used as feed again (Moriya and Kitagawa, 2007; Matsumoto and Matsuyama 1995).

However, increased amounts of manure must be treated, broken down into biologically safe and usable materials, and disposed in a safe way. Livestock manure treatment is generally accomplished by moving manure into either large manure-holding structures or earthen holding areas called lagoons. In the pond-like lagoons, bacteria break down the manure into two products: a clear water called effluent that can be drained off and a sludge that is generally applied to surrounding land (IAN. 1998).

Animal manure can be an important addition to help soil fertility and increase production, but excessive quantities may cause water and air pollution problems. But land application of manure to recycle nutrients can lead to an accumulation of soil nitrogen and phosphorus which in turn increases the potential for losses by runoff and leaching. Taking this into consideration, the following choices are possible to keep the environmental capacity in control:

1) Excreta cannot be discharged beyond the environmental capacity. Decrease the quantity of excreta to keep the capacity.
2) More excreta than the environmental capacity can be discharged. In that case, however, the excreta must be treated.

With regard to (1), because the quantity of excreta produced at a farm is the total of the excreta from each animal kept there, the measures are naturally suggested: (a) decrease the number of animals; or (b) decrease the quantity of excreta per animal (per weight). However, as (b) is not supposed to be easy to carry out, (a) is the realistic measure. In order to reduce the number of animals and maintain the business at the same time, the value per animal needs to be enhanced. With regard to (2), the measure is to implement an actual excreta disposal method (Kawata, 2011).

Paddy Cum Fish Culture

The system of farming is most prevalent in Japan, China, Indonesia, India, Thailand and Philippines. Many reports suggest that integrated rice-fish farming is ecologically sound because fish improve soil fertility by increasing the availability of nitrogen and phosphorus (Giap et al., 2005, Dugan et al., 2006). On the other hand, rice fields provide fish with planktonic, periphytic and benthic food (Mustow, 2002).
In paddy cum fish culture the fish species selected for cultivation should have faster growth rate. Species such as Catla catla, Labeo rohita, Cirrhinus mrigala, Cyperinus carpio, Tilapia mossambicus, Anabas, Clarius batarchus and Channa species were widely cultured in rice field (Shamsuddin, 2013). Table 2 shows the comparison between environmental requirements of rice and fish

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Normal range</th>
<th>Rice</th>
<th>Fish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of water</td>
<td>Minimum saturated soils with no flooding&lt;br&gt;Ideal: Continuous flooding started at 3 cm depth gradually increasing to max of 15 cm by 60th day. Complete draining 1-2 weeks before harvest (Singh et al 1980)</td>
<td>0.4 – 1.5 m for nursery and 0.8 to 3.0 m for grow out (Pillay 1990)</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>Water and soil temperature of up to 40°C and fluctuations of up to 10°C in one day apparently with no deleterious effect.</td>
<td>25 °C to 35 °C for warm water species. Stable temperature preferable. Feeding may slow down at temperatures below or above normal range. Metabolic rate doubles almost</td>
<td></td>
</tr>
<tr>
<td>pH of water</td>
<td>Neutral to alkaline</td>
<td>6.5 to 9.0 (Boyd 1979)</td>
<td></td>
</tr>
<tr>
<td>Oxygen</td>
<td>Important during seedling stage for development of radicles</td>
<td>Preferably at near saturation or saturation level (5.0 to 7.5 ppm depending on temperature)</td>
<td></td>
</tr>
<tr>
<td>Ammonia</td>
<td>High levels of ammonia common immediately after fertilization</td>
<td>Un-ionized ammonia highly toxic. Ionised forms generally safe</td>
<td></td>
</tr>
<tr>
<td>Transparency or Turbidity</td>
<td>Immaterial</td>
<td>Important for growth of natural food. Very high level of suspended soil particles may impair respiration</td>
<td></td>
</tr>
<tr>
<td>Culture period</td>
<td>90-120 days for high yielding varieties, up to 160 days for traditional varieties</td>
<td>120-240 days depending upon species and market requirement.</td>
<td></td>
</tr>
</tbody>
</table>

ROLE OF IFS IN IMPROVING SOIL HEALTH AND NUTRIENT CYCLING

Soil health is declining in many cropping systems both in developed and developing countries (FAO, 2011). The ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) consortium team assessed 3622 soil samples from the farmers’ fields in different states of India (Andhra Pradesh, Karnataka, Rajasthan, Madhya Pradesh, Gujarat and Tamil Nadu) and observed widespread deficiencies of sulfur (S), zinc (Zn) and boron (B), along with total nitrogen (N) and phosphorus (P) (Sahrawat et al., 2008) (Table 3).

<table>
<thead>
<tr>
<th>State</th>
<th>Org. C (%)</th>
<th>Nutrients (mg/kg soil)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Av.P</td>
<td>K</td>
</tr>
<tr>
<td>Andhra Pradesh</td>
<td>84</td>
<td>39</td>
</tr>
<tr>
<td>Karnataka</td>
<td>58</td>
<td>49</td>
</tr>
<tr>
<td>Madhya Pradesh</td>
<td>9</td>
<td>86</td>
</tr>
<tr>
<td>Rajasthan</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>Gujarat</td>
<td>12</td>
<td>60</td>
</tr>
<tr>
<td>Tamil Nadu</td>
<td>57</td>
<td>51</td>
</tr>
<tr>
<td>Kerala</td>
<td>11</td>
<td>21</td>
</tr>
</tbody>
</table>

IFS also play an important role in improving the soil health by increasing the nutritional value of soil. The benefits of the use of livestock manure in crop production are improvements in soil physical properties and the provision of N, P, K and other mineral nutrients. The application of livestock manure increases soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity. Manure and urine raise the pH level and accelerate the decomposition of organic matter and termite activity (Brouwer and Powell, 1995; 1998).
Channabasavanna et al. (2002) reported the changes in chemical properties of soil under rice-based farming systems (Table 4). The available N, P$_2$O$_5$ and K$_2$O contents of soil varied significantly. Maximum available N was recorded in rice (fish)-rice (fish) with poultry and minimum in rice-rice system. The maximum P$_2$O$_5$ was recorded in rice (GLM)-rice (GM) systems followed by rice (fish)-rice (fish) with poultry and rice-rice with dairy. The rice (fish) - rice (fish) with or without poultry recorded the highest available K$_2$O in soil.

<table>
<thead>
<tr>
<th>Table 4: Soil nutrients as influenced by rice based farming systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Rice-rice</td>
</tr>
<tr>
<td>Rice-sesame</td>
</tr>
<tr>
<td>Rice-chilli</td>
</tr>
<tr>
<td>Rice-wheat-GM</td>
</tr>
<tr>
<td>Rice+Fish(Ri)- Rice+Fish(dung)</td>
</tr>
<tr>
<td>Rice+Fish(Ri)+ Rice+Fish(poultry)- poultry</td>
</tr>
<tr>
<td>Rice+Fish(Ri)- Rice+Fish(fish feed)</td>
</tr>
<tr>
<td>Rice-rice-banana on bunds</td>
</tr>
<tr>
<td>Rice-rice-drumstick and curry leaf on bunds</td>
</tr>
<tr>
<td>Rice-rice-pargrass and cowpea on bunds+ dairy</td>
</tr>
<tr>
<td>Rice GLM- rice</td>
</tr>
<tr>
<td>Rice-rice-GM</td>
</tr>
</tbody>
</table>

Source: Channabasavanna et al., 2002

Channabasavanna and Biradar (2007) reported that nutritional status of soil N show increased trend from 187 kg/ha to 362 kg/ha (40%) in rice-fish poultry system (Table 5). The increase was to the tune of 11.5% over conventional systems. Similarly, P and K content showed increased trend with IFS.

<table>
<thead>
<tr>
<th>Table 5: Water requirement and NPK status after experimentation on IFS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatments</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>Integrated farming system</td>
</tr>
<tr>
<td>Rice-fish(pit at one side) and poultry (shed on fish pit)</td>
</tr>
<tr>
<td>Rice-fish(pit at one side connected by trenches) and poultry (shed on fish pit)</td>
</tr>
<tr>
<td>Rice-fish(pit at the centre) and poultry (reared separately)</td>
</tr>
<tr>
<td>Rice-fish(pit at one centre connected by trenches) and poultry (reared separately)</td>
</tr>
<tr>
<td>Rice-fish(pit at four corners connected by trenches) and poultry (reared separately)</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Conventional cropping system</td>
</tr>
<tr>
<td>Control(rice-rice system)</td>
</tr>
</tbody>
</table>

*Mean over two years, **Initial level
Source: Channabasavanna and Biradar, 2007

Solaippan et al. (2007) examined different farming system models such as (A) Conventional cropping, (B) Crop+ poultry(20) + goat (4), (C) Crop+ poultry(20) + goat (4) + dairy (1), (D) Crop+ poultry(20) + goat (4) + sheep (6) and (E) Crop+ poultry(20) + goat (4) + sheep (6) + dairy (1) and found IFS model (E) recorded maximum organic carbon (0.35%), available soil N (134 kg / ha), soil P (8.5 kg/ha) and soil K (378kg/ha) at the end of study (Table 6).
Table 6: Available soil N, P and K (kg/ha) and organic C (%) at the start and completion of the study under different farming system models

<table>
<thead>
<tr>
<th>Model</th>
<th>2003</th>
<th></th>
<th>2005</th>
<th></th>
<th>Increase %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>115</td>
<td>7.7</td>
<td>310</td>
<td>0.28</td>
<td>118</td>
<td>8.1</td>
</tr>
<tr>
<td>B</td>
<td>114</td>
<td>7.5</td>
<td>312</td>
<td>0.25</td>
<td>124</td>
<td>8.3</td>
</tr>
<tr>
<td>C</td>
<td>120</td>
<td>7.3</td>
<td>315</td>
<td>0.26</td>
<td>132</td>
<td>8.3</td>
</tr>
<tr>
<td>D</td>
<td>118</td>
<td>7.5</td>
<td>318</td>
<td>0.27</td>
<td>128</td>
<td>8.4</td>
</tr>
<tr>
<td>E</td>
<td>121</td>
<td>7.4</td>
<td>314</td>
<td>0.27</td>
<td>134</td>
<td>8.5</td>
</tr>
<tr>
<td>Mean</td>
<td>118</td>
<td>7.5</td>
<td>314</td>
<td>0.27</td>
<td>127</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Source: Solaiappan et al., 2007
Nageswaran et al. (2009) studies the various soil parameters for comparing the IFS and CFS and found neutrality of pH was attained in IFS plot possibly due to intensive application of organic input while in CFS there was building up of salt leading to alkalinity. The concentration of organic carbon and population of microbes namely bacteria, actinomycetes and fungi in IFS have shown an increasing trend. All these parameters are actually indicators of good soil health (Table 7 and Table 8).

Table 7: Data on Soil pH and Organic carbon (%) at eight observation points between 1998 and 2002 in the IFS and two conventional farms.

<table>
<thead>
<tr>
<th>Year</th>
<th>Soil pH</th>
<th>Organic Carbon (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IFS</td>
<td>CFS I</td>
</tr>
<tr>
<td>Nov 98</td>
<td>7.80</td>
<td>7.60</td>
</tr>
<tr>
<td>Apr 99</td>
<td>7.50</td>
<td>7.84</td>
</tr>
<tr>
<td>Nov 99</td>
<td>7.69</td>
<td>7.89</td>
</tr>
<tr>
<td>Feb 00</td>
<td>7.82</td>
<td>7.95</td>
</tr>
<tr>
<td>Nov 00</td>
<td>7.68</td>
<td>8.13</td>
</tr>
<tr>
<td>Apr 01</td>
<td>7.68</td>
<td>8.28</td>
</tr>
<tr>
<td>Nov 01</td>
<td>7.80</td>
<td>7.80</td>
</tr>
<tr>
<td>Apr 02</td>
<td>7.00</td>
<td>7.40</td>
</tr>
</tbody>
</table>

Source: Nageswaran et al., 2009

Table 8: Microbial population (million) in the IFS and two conventional farms

<table>
<thead>
<tr>
<th></th>
<th>IFS</th>
<th>CFS I</th>
<th>CFS II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria THC(X 10^5)</td>
<td>94</td>
<td>46</td>
<td>56</td>
</tr>
<tr>
<td>Actinomycetes CFU (X 10^4)</td>
<td>42</td>
<td>6</td>
<td>15</td>
</tr>
<tr>
<td>Fungi CFFU(X 10^3)</td>
<td>86</td>
<td>44</td>
<td>55</td>
</tr>
</tbody>
</table>

Source: Nageswaran et al., 2009

The rice fish prawn system of Mohanty et al. (2010) revealed the levels of organic carbon, available nitrogen and phosphorous in the soil showed significant higher increments in the deepwater rice-fish prawn system than in the rice monocarp system (Table 9). This may be attributed to additional nutrients from fish feed and faeces and fish grazing on the photosynthetic aquatic biomass and other components of the system which aids in nutrient recycling.

Table 9: Soil and water quality parameters in rice monocarp and rice-fish prawn systems

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rice monocarp</th>
<th>Rice-fish prawn system</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.52 (6.7-8.1)</td>
<td>7.31 (6.9-8.5)</td>
</tr>
<tr>
<td>Dissolved oxygen (ppm)</td>
<td>6.1 (4.4-8.9)</td>
<td>4.9 (3.3-8.4)</td>
</tr>
<tr>
<td>Temperature (ºC)</td>
<td>28.7 (27.9-31.5)</td>
<td>28.4 (27.3-31.4)</td>
</tr>
<tr>
<td>Total alkalinity(ppm)</td>
<td>83 (73-107)</td>
<td>94 (68-109)</td>
</tr>
<tr>
<td>Dissolved organic matter (ppm)</td>
<td>2.6 (0.55-3.6)</td>
<td>3.4 (1.45-4.8)</td>
</tr>
<tr>
<td>TSS (ppm)</td>
<td>177 (60-257)</td>
<td>225 (132-297)</td>
</tr>
<tr>
<td>NH4+ water (ppm)</td>
<td>0.59 (0.41-0.91)</td>
<td>0.68 (0.34-0.97)</td>
</tr>
<tr>
<td>Chlorophyll a (mg/m³)</td>
<td>22.3 (18.8-31.3)</td>
<td>41.1 (21.1-62.2)</td>
</tr>
<tr>
<td>Total plankton (units/l)</td>
<td>7.3 X 10^4 (9.4 X 10^4 - 1.8 X 10^4)</td>
<td>3.3 X 10^4 (2.9 X 10^4 - 6.7 X 10^4)</td>
</tr>
<tr>
<td>Nitrite – N (ppm)</td>
<td>0.033 (0.011-0.07)</td>
<td>0.037 (0.012-0.072)</td>
</tr>
<tr>
<td>Nitrate- N (ppm)</td>
<td>0.36 (0.16-0.61)</td>
<td>0.37 (0.05-0.49)</td>
</tr>
<tr>
<td>Phosphate (ppm)</td>
<td>0.26 (0.13-0.54)</td>
<td>0.21 (0.06-0.33)</td>
</tr>
<tr>
<td>Available N in soil (mg 100/g)</td>
<td>19.3 (20.1-21.9)</td>
<td>20.3 (17.9-21.6)</td>
</tr>
<tr>
<td>Available P in soil (mg 100/g)</td>
<td>2.11 (1.63-2.89)</td>
<td>2.23 (1.28-2.93)</td>
</tr>
<tr>
<td>Organic carbon in soil (%)</td>
<td>0.62 (0.57-0.75)</td>
<td>0.66 (0.49-0.82)</td>
</tr>
<tr>
<td>Soil pH</td>
<td>6.94 (6.6-7.1)</td>
<td>7.01 (6.8-7.1)</td>
</tr>
</tbody>
</table>

Values in parentheses represent range

Source: Mohanty et al., 2010
ROLE OF IFS COMPONENTS IN WEED AND PEST CONTROL

One problem in agricultural environment is related to the use of some pesticides (Turral and Burke, 2010). Pest and weed management has been a recurrent issue in irrigated agriculture since the emergence of modern large-scale rice and wheat farming. In monocultures, pests and diseases can spread rapidly and result in epidemics when conditions are favourable to a particular pathogen or pest. Some high-yielding varieties of rice have proved to be susceptible to particular pests (e.g. IR64 to brown plant hopper). Agricultural run-off and drainage readily transport the pesticide pollutants to water bodies and causing a great harm.

Conventional cropping systems in the Central USA have low levels of biological diversity and rely heavily on synthetic fertilizers and herbicides. These are common contaminatees of waterways and cause environmental degradation. Ecological theory suggests that diversified cropping systems integrated with livestock should have a reduced reliance on chemicals and fertilizers and should lower production costs and environmental pollution (Liebman, 2008).

Network trails conducted at various sites in France revealed that amount of herbicides, insecticides, chemical fertilizers and fungicides used in IFS compared with Conventional Farming System (CFS) decreased by 10.1, 28.3, 41.3 and 89.8 percent respectively (Table 10).

Table 10: Reduction of inputs at Saint-Hilaire (1991-95) and reduction of wheat yields at Boigneville (1991-94) for Integrated Farming Systems compared with Conventional Farming Systems

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed (+2.6)</td>
<td>1991(-34.6)</td>
</tr>
<tr>
<td>Herbicide (-10.1)</td>
<td>1992(-19.6)</td>
</tr>
<tr>
<td>Insecticide (-28.3)</td>
<td>1993(-15.9)</td>
</tr>
<tr>
<td>Fertilizer (-41.3)</td>
<td>1994(-14.8)</td>
</tr>
<tr>
<td>Fungicide (-89.8)</td>
<td>Mean(-21.2)</td>
</tr>
</tbody>
</table>

Compared with using herbicides, which need protective measures to minimize contamination, the use of animals is safer for the farmer and the environment. In Malaysia, the use of sheep for weed control has been a practical and important method for the expansion of sheep production in the country, which has increased the returns per unit area of land (Devendra and Thomas, 2002).

Long term effects of integrating fish and poultry components with rice have been studied by Kathiresan (2007) which indicated that fish and poultry components independently contributed for 26 and 24% weed control respectively and fish + poultry together contributed for 30% weed control. The same study also proved that application of sugar factory bi-product presumed as organic manure with dual culturing of bio-fertilizer Azolla in the integrated rice + fish + poultry farming system could offer 69% weed control, paving then way to dispense with herbicide application (Gunasekaran and Kathiresan, 2003).

Kathiresan (2009) reported that the herbivores fish species viz. grass carp (Ctenopharyngodon idella), Tilapia sp. (Sarotherodon niloticus) and Common carp (Cyprinus carpio) contributing for significantly higher biomass reduction in the three weed species viz. 33.17% of Echinochloa sp.; 31.82% of Cyperus rotundus and 28.75% of Eclipta alba in rice-fish integrated farming system (Table 11). Kathiresan (2009) found that grazing by goats in the off-season reduced weed infestation in millets during the cropping season through their feeding habits but addition of fresh goat manure slightly brought down weed control by virtue of effect by favouring higher weed counts and biomass especially with annuals, compared to grazing alone (Table 12). This is attributed to re-infestation by annual weed seeds through the goat manure by virtue of the process of endozoochory. However, the total weed count and weed biomass in the treatments involving goat manure addition were significantly lesser than the untreated control. This weed control might be due to reduced soil pH and reduced recuperation of soil weed bank. Goat rearing, when integrated as a farming component in dry lands where millet was grown during cropping season, supplemented weed control and reduced weed infestation, significantly by imparting weed control indices of 17.7% and 31.34% during the first and second year respectively. Excluding goat manure addition, grazing alone supplemented weed control in millets recording weed control indices of 25.20% and 45.17% respectively (Geetha et al., 2005). This could be appreciated from higher grain yields in goat grazing alone compared to treatments involving goat grazing + goat manuring. It could be suggested that instead of adding fresh manure to the field, allowing the goat manure to decompose throughout the offseason and incorporating it in the field just before raising the crop, could yield better results in terms of reducing weed competition and favouring millet yields.
Table 11: Percentage reduction in biomass of weeds in rice fish integrated farming system

<table>
<thead>
<tr>
<th>Fish species</th>
<th><em>Echinochloa</em> sp.</th>
<th><em>Cyperus rotundus</em></th>
<th><em>Eclipta alba</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass carp</td>
<td>33.17</td>
<td>31.82</td>
<td>28.75</td>
</tr>
<tr>
<td>Tilapia</td>
<td>15.48</td>
<td>14.00</td>
<td>14.59</td>
</tr>
<tr>
<td>Common carp</td>
<td>22.37</td>
<td>20.86</td>
<td>18.00</td>
</tr>
<tr>
<td>Grass carp and Tilapia</td>
<td>21.02</td>
<td>19.80</td>
<td>16.73</td>
</tr>
<tr>
<td>Grass Carp and common carp</td>
<td>28.13</td>
<td>25.18</td>
<td>22.78</td>
</tr>
<tr>
<td>Tilapia and common carp</td>
<td>20.46</td>
<td>18.74</td>
<td>16.01</td>
</tr>
<tr>
<td>Grass carp, Tilapia and common carp</td>
<td>23.65</td>
<td>0.86</td>
<td>21.71</td>
</tr>
</tbody>
</table>

Source: Kathiresan, 2009

Table 12: Effect of grazing on weeds in IFS

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Weed biomass (g/m²)</th>
<th>Weed control index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2003</td>
<td>2004</td>
</tr>
<tr>
<td>Control</td>
<td>83.90</td>
<td>62.25</td>
</tr>
<tr>
<td>Goat grazing</td>
<td>62.76</td>
<td>34.13</td>
</tr>
<tr>
<td>Penning</td>
<td>74.45</td>
<td>42.74</td>
</tr>
<tr>
<td>Grazing and penning</td>
<td>69.04</td>
<td>39.75</td>
</tr>
<tr>
<td>CD (P=0.05)</td>
<td>6.09</td>
<td>4.92</td>
</tr>
</tbody>
</table>

Source: Kathiresan, 2009

Integrated rice-fish farming is also being regarded as an important element of integrated pest management (IPM) in rice crops (Berg, 2001, Halwart and Gupta, 2004). Fish play a significant role in controlling aquatic weeds and algae that carry diseases, act as hosts for pests and compete with rice for nutrients. Moreover, fish eat flies, snails and insects, and can help to control malaria mosquitoes and water-borne diseases (Matteson, 2000). Interactions of fish and rice also help lower production costs because insects and pests are consumed by the fish. The bio-control of rice pests is one of the prominent features of rice–fish farming which further minimize the use of pesticides for production of rice crop.

Bingyou et al. (2001) and Zhonghua (1996) based on their results, found that fish could play an effective role as a bio-control agent against rice pests and diseases as showed in Table 13 and Table 14 respectively.

Table 13: The effect of bio-control of rice pests and diseases in rice-fish ecosystems

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rice plant hopper</th>
<th><em>Naranga aenescens</em> Moore</th>
<th><em>Parnara guttata</em> Bremer &amp; Grey</th>
<th>Rice leaf roller</th>
<th>Rice leaf hopper</th>
<th>Sheath rot (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice monoculture</td>
<td>237</td>
<td>534</td>
<td>20</td>
<td>11</td>
<td>839</td>
<td>37.7</td>
</tr>
<tr>
<td>Rice fish system</td>
<td>75</td>
<td>107</td>
<td>10</td>
<td>6</td>
<td>227</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Source: Bingyou et al. (2001)

Table 14: The incidence of rice pests, rice diseases and weeds in rice-fish system

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rice plant hopper (%)</th>
<th>Rice blast (%)</th>
<th>Sheath rot (%)</th>
<th>Quantity of weeds (numbers/m²)</th>
<th>Biomass of weeds (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice monoculture</td>
<td>8.3</td>
<td>51.3</td>
<td>20.9</td>
<td>46-50</td>
<td>420-460</td>
</tr>
<tr>
<td>Rice fish system</td>
<td>2.7</td>
<td>27.4</td>
<td>6.7</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: Zhonghua (1996)
WATER USE EFFICIENCY AND WATER QUALITY IN IFS

Agriculture is the largest consumer of water in the world. The quantity of water available to agriculture is likely to be affected by dwindling of the groundwater resource in many areas. Widespread and largely unregulated groundwater withdrawals by agriculture have resulted in depletion and degradation of some of the world's most accessible and high-quality aquifers and such areas include Punjab, North China Plain and the Souss basin in Morocco, where annual declines of up to 2 metres since 1980 have been recorded (Garduno and Foster, 2011). Due to demand of water for industrial and drinking purposes, the share of available water resources in agriculture sector is reducing substantially in near future. IFS results in multiple uses of water for higher productivity and future strategies for enhancing water productivity (Behera et al., 2012).

Rice itself is a water consuming crop. Addition of fish still increased the water requirement. Channabasavanna and Biradar (2007) reported that IFS consumed 36% higher water than the conventional system of rice-rice but the water use efficiency was 71% higher in IFS than conventional system (Table 4). Earlier, Jayanthi et al. (2000) indicated that integrated farming requires less water per unit of production than mono-cropping systems. Channabasavanna et al. (2009) also reported that integrated farming system requires only 1247 mm of water and on the other hand conventional farming system requires 2370 mm of water.

The various agricultural activities involved have far reaching impacts upon the hydrological cycle due to high usage of pesticides and fertilizers. Oksel et al. (2009) carried out the studies to determine the impacts of integrated farming towards Langgas River water quality. From the overall finding, the study indicated that integrated farming affected Langgas River water quality but in the value is still within the acceptable limit. From the mean concentration results, Langgas River is free from organic contamination. Four different sampling points were chosen which consumed of upper part of Langgas River; consisted of clear water flowing over series of shallow gravel riffles (Station 1), downstream of Langgas River which is border of the estate (Station 2), middle of Langgas River (Station 3) and Madai Waterfall as the baseline point (Station 4). A total of ten water quality parameters were studied which consisted of phosphate, ammonia-nitrogen, biological oxygen demand (BOD), chemical oxygen demand (COD), turbidity, temperature, dissolved oxygen (DO), pH, conductivity and total suspended solid (TSS). Four sampling points were selected within Langgas River which is associated with integrated farming activity which consist of upstream, downstream, middle and Madai Waterfall (baseline station). Mean concentrations of water quality are summarized in Table 15. With regards to Malaysian Interim Water Quality Standard (INWQS), indicates that Langgas River still has good water quality.

Table 15: Mean water quality concentrations associated with integrated farming activity

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphate (mg/L)</td>
<td>0.55</td>
<td>0.67</td>
<td>0.64</td>
<td>0.85</td>
</tr>
<tr>
<td>Ammonianitrogen (mg/L)</td>
<td>0.01</td>
<td>0</td>
<td>0.05</td>
<td>0.06</td>
</tr>
<tr>
<td>BOD (mg/L)</td>
<td>0.56</td>
<td>0.69</td>
<td>0.57</td>
<td>0.65</td>
</tr>
<tr>
<td>COD (mg/L)</td>
<td>0.67</td>
<td>4.33</td>
<td>3.33</td>
<td>2.10</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>2.82</td>
<td>1.50</td>
<td>20.8</td>
<td>20.3</td>
</tr>
<tr>
<td>Temperature (ºC)</td>
<td>28.0</td>
<td>27.5</td>
<td>27.2</td>
<td>28.62</td>
</tr>
<tr>
<td>DO (mg/L)</td>
<td>6.81</td>
<td>5.86</td>
<td>4.11</td>
<td>7.05</td>
</tr>
<tr>
<td>pH</td>
<td>8.10</td>
<td>8.44</td>
<td>7.71</td>
<td>8.21</td>
</tr>
<tr>
<td>Conductivity (mS/cm)</td>
<td>0.56</td>
<td>0.54</td>
<td>0.63</td>
<td>0.31</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>4.3</td>
<td>3.57</td>
<td>17.8</td>
<td>17.4</td>
</tr>
</tbody>
</table>

Source: Oksel et al., 2009
CONCLUSION

IFS is also an eco-friendly approach in which waste of one enterprise becomes the input of another thus making efficient use of resources. It helps in improving the soil health, weed and pest control, increase water use efficiency and maintains water quality. As this system minimizes the use of harmful chemical fertilizers, weed killers and pesticides and thus safeguards the environment from the adverse effects.

REFERENCES


