Water Used for Agriculture in the Lower Mekong Basin

MRC Discussion Paper

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Executive summary

More than 41% of the watershed areas in the Lower Mekong Basin (LMB) are used for agricultural production and the area under cultivation is steadily expanding to produce more food for the burgeoning populations of Cambodia, Lao PDR, Thailand, and Viet Nam.

Agriculture is also responsible for 80-90% of all water abstractions from the Mekong river, most of which is for crop cultivation. Crop irrigation, animal raising and fish farm operation occur almost exclusively on flatter terrains. Within this land type, 64% of the area is utilised for agriculture. The largest non-cultivated area is in Cambodia. The majority of the soils in the flatter areas are infertile acrisols, which have proved to be low agronomic producers. The fertility of these soils and others improves when they are flooded to a point where the root zone becomes anaerobic, and then releases nutrients. Rice is an ideal plant to grow in waterlogged and slightly flooded conditions and, for this reason, rice is by far the dominant crop grown in the LMB.

Fertiliser and pesticide use is low in rain-fed areas but increases with irrigation as farmers spend more money on chemical inputs to promote crop growth and protect their investment. Chemical leakage into the river system is currently not affecting water quality except on the Mekong Delta in Viet Nam where canal and river water pollution is becoming a problem in aquaculture areas.

Access to water is a major constraint to increasing crop yields in the LMB and there is continuing installation and improvement of irrigation schemes in each of the four countries to lift production. Most of the water is derived from surface reservoirs or directly from the river, although groundwater is important for coffee farmers in the central highlands of Viet Nam and Lao PDR, some fruit growers in the Mekong Delta and an increasing number of rice growers in Cambodia.

Available water reserves are not fully utilised in NE Thailand because crop yields on the infertile soils are low and uneconomic, especially in the dry season. Better soils and a high level of renewable water resources mean the potential for irrigation development is greater in Lao PDR than the other three countries. There is 10 million ha of potentially irrigable land in Cambodia, some of which could be developed for irrigation, while the remainder could be cultivated to upland and perennial crops or cleared for grazing.
The Mekong Delta in Viet Nam faces problems with accessing water during the critical months of February-May. Cultivation of rice during this period is responsible for most of the current abstractions from the Mekong River. New farming systems proposed by the Government for each of the ecological zones in the delta may reduce the amount of water consumed by rice, but increase the level of abstractions by upland crops, perennials and fish/shrimp ponds. These abstractions are more likely to occur during the critical period, especially for crops susceptible to water logging at the beginning and end of the dry season. Farmers also need to reduce the risks of changing from one farming system to another.

Progress on developing strategies for farmers to lessen the risks associated with using more water efficient farming practices are dependent on improvements in marketing of produce, storage and agro-processing facilities, pest control, water quality and stress, availability of labour and capital, improved plant nutrition and knowledge.
1 Introduction

The aims of the Mekong River Commission’s Basin Development Plan (BDP) are “to contribute to acceleration of inter-dependent sub-regional growth by establishing a process and a framework conducive to investment and sustainable development. The BDP is establishing a planning framework for development programmes aimed at balancing efficient use of resources with protection of the environment and promotion of social justice and equity” (MRC, 2002a). The following review on water used for agriculture in the Lower Mekong Basin (LMB) is part of the process of establishing that framework. The review will discuss the current farming systems employed in the LMB, the rationale for their adoption, the potential for change and implications the current and future farming systems will have on abstraction of water from the Mekong river system. The discussion of these issues has the following outline:

- A short description of the study area
- A brief review of current farming systems in the LMB including cropping systems, animals, fish and shrimp production
- Why rice dominates agriculture in the LMB, preference for dry season production and some rice cultivation techniques
- Constraints to crop production including soils, fertilisers and pesticides, farm mechanisation, marketing and agro-processing, credit and irrigation water
- Discussion on current water consumption, identification of potential alternative farming systems with varying water consumptions and limitations to their adoption
- A short review of water quality in the LMB
- Government policies and potential for agricultural development in the LMB watersheds
- Identification and discussion of risk reduction measures for cropping systems
- Reviewing current research work and trials to expand the range of systems for productivity and profitability improvement
2 The study area

The Lower Mekong Basin study area is comprised of watersheds (catchments) in the majority of provinces in the Lao PDR (97% of country); three provinces in the Central Highlands and a major proportion of the Mekong River Delta region of Viet Nam (20% of country); most of Cambodia (86% of country); and the NE plus a part of Northern Thailand (36% of country) (Figure 1).

Parts of Myanmar and of the Yunnan province of China are included in the entire Mekong valley catchment and approximately 18% of the total 460 cubic kilometres (km3) of water which flows annually down the Mekong River originates from outside of the LMB. The left bank tributaries in Lao PDR contribute the largest proportion of total flow (Halcrow, 2003). Catchments in Lao PDR provide 35% of the total flow of the river, 18% comes from Thailand, 18% from Cambodia and 11% from Viet Nam (MRC, 2002b).

Agriculture is by far the most important activity in the LMB, providing livelihoods for a majority of its residents. The population of the basin has grown by nearly 50% since 1980 and projections forecast a similar growth rate for at least the next 20 years, and the increased demand for food will place further pressure on the land.

Although the total catchment area in the LMB is 60.6 million ha, much of the land in the central highlands of Viet Nam, many of the provinces in Lao PDR and parts of Thailand and Cambodia are mountainous and remain uncleared. The MRC watershed classification system classes these areas (Figure 2, Table 1) as having high or moderate levels of degradation potential and should remain uncleared or be managed carefully.

Very steep slopes and rugged landforms (Class 1), which should remain forested to prevent serious soil erosion, make up 7% of the total area, while steep slopes at higher elevation (Class 2) account for a further 16%.

These steep slopes, moderately-steep slopes (Class 3) and gently sloping land suitable for upland cultivation (Class 4) are used for slash and burn agriculture, some agro-forestry and upland crops including upland rice, maize, cassava and legumes. They are not suitable for irrigation.

Thirty nine per cent of Class 4 land (17% of the total area) is currently utilised for agriculture, usually for upland crop production and industrial tree crops. Much of the undeveloped areas are in Lao PDR and eastern Cambodia (Table 2).

Forty nine percent of the total LMB area is classified as Class 5 land consisting of gentle slopes and flat areas that are potentially suitable for irrigation (Table 3). Seventy percent of this area is in NE Thailand and Cambodia. Approximately 72% of the watershed in Cambodia is classified in Class 5, 13% of Lao PDR, 65% of Thailand,
Figure 1. Classes of watershed land types in the LMB
11% of the central highlands of Viet Nam and 99% of the Mekong Delta. Despite the high percentage of the watershed land categorised as Class 5, the area being utilised for irrigation remains small (Table 4). The utilisation rate for irrigated agriculture currently runs at 13-14% across the LMB for both the dry and wet season, although much of this is partial irrigation. Section 14 of this report gives a fuller discussion of the reasons for the low adoption of irrigation.

3 Typical cropping systems in the LMB

The dominance of rice cultivation predicates the cropping systems employed in the LMB (see Sections 6, 7 and 8 for more details). Rain-fed rice dominates farming in Lao PDR, the central highlands of Viet Nam, NE Thailand and Cambodia, while fully or partially irrigated rice is grown year round in parts of the Mekong Delta of Viet Nam (Table 5a). The area of land dedicated to growing upland crops (Table 5a and Table 5b) is much smaller in total than that planted to rice and fluctuates in area from year to year. Fruit and industrial crop production is expanding rapidly from a low base (Table 5c, MAC, 2000; BLS 2001; MAFF, Cambodia 2000, VSY, 2002).

Rain-fed rice is generally sown at the beginning of the wet season (May-June) and

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Table 1. MRC Watershed classification systems and areas.

<table>
<thead>
<tr>
<th>Class</th>
<th>Area description</th>
<th>Recommended land suitability</th>
<th>% of LMB</th>
<th>Area utilised (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1</td>
<td>Steep slopes and rugged landforms</td>
<td>Permanent forest cover</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Class 2</td>
<td>Steep slopes at higher elevations</td>
<td>Production forests, agro - forestry and grazing</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td>Class 3</td>
<td>Moderate to steep slopes and less eroded landforms</td>
<td>Commercial forests, grazing and agro-forestry</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Class 4</td>
<td>Gently sloping land</td>
<td>Upland agriculture</td>
<td>17</td>
<td>39</td>
</tr>
<tr>
<td>Class 5</td>
<td>Gently sloping land and flat areas</td>
<td>Upland crops and paddy rice</td>
<td>49</td>
<td>63</td>
</tr>
</tbody>
</table>

TOTAL 100 41

Table 2. Areas of Class 4 (gentle slopes) land in LMB Zones

<table>
<thead>
<tr>
<th>Watershed area</th>
<th>% of LMB watershed area</th>
<th>Area of Class 4 land (000 ha)</th>
<th>Area utilised (000 ha)</th>
<th>Area utilised (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>5</td>
<td>2,941</td>
<td>144</td>
<td>5</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>5</td>
<td>3,051</td>
<td>762</td>
<td>25</td>
</tr>
<tr>
<td>Thailand NE and part N</td>
<td>6</td>
<td>3,601</td>
<td>2,696</td>
<td>75</td>
</tr>
<tr>
<td>Viet Nam CH</td>
<td>2</td>
<td>1,131</td>
<td>581</td>
<td>51</td>
</tr>
<tr>
<td>Viet Nam MD</td>
<td>0</td>
<td>10</td>
<td>7</td>
<td>68</td>
</tr>
</tbody>
</table>

TOTAL 17 10,635 4,189 39

Note: Source MRC. CH = Central Highlands, MD = Mekong Delta.
harvested from October through to the following January, depending on the maturity of the cultivated variety (Figure 3). These crops may be direct seeded or transplanted (see section 8.5). Double cropping in the wet season is now possible with recently introduced faster maturing High Yielding Varieties (HYVs). This practice is more common in Cambodia than in other countries and is gaining popularity in areas where there is sufficient rainfall to plant a HYV early in the wet season and harvest it in time to transplant a second traditional, photoperiod sensitive variety. Some early wet season crops may receive suplemental irrigation.

The total area of land cultivated to rice in the LMB during the wet season is currently well over 10 million ha. Approximately 9.5 million ha is harvested. It is currently estimated (MRC figures in Table 4) that over 4 million ha of wet season rice receives some form of supplemental irrigation. If drainage from one field to another is included in the calculation, the area may be much greater. Included in this estimate are about 750,000 ha of nursery in NE Thailand, Lao PDR, Cambodia and the central highlands of Viet Nam receiving extra water prior to transplanting in June, July or August.

Table 3. Areas of Class 5 (Gentle slopes and flat) land in LMB Zones

<table>
<thead>
<tr>
<th>Watershed area</th>
<th>% of LMB watershed area</th>
<th>Watershed area Class 5 (%)</th>
<th>Area of Class 5 (000 ha)</th>
<th>Area utilised (000 ha)</th>
<th>Area utilised (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>18</td>
<td>72</td>
<td>11,243</td>
<td>3,481</td>
<td>31</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>5</td>
<td>13</td>
<td>2,317</td>
<td>944</td>
<td>41</td>
</tr>
<tr>
<td>Thailand NE and part N</td>
<td>20</td>
<td>65</td>
<td>12,157</td>
<td>11,543</td>
<td>95</td>
</tr>
<tr>
<td>Viet Nam CH</td>
<td>1</td>
<td>11</td>
<td>361</td>
<td>129</td>
<td>36</td>
</tr>
<tr>
<td>Viet Nam MD</td>
<td>5</td>
<td>66</td>
<td>3,256</td>
<td>2,868</td>
<td>88</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>49</strong></td>
<td><strong>29,334</strong></td>
<td><strong>18,966</strong></td>
<td><strong>13.4</strong></td>
<td><strong>65</strong></td>
</tr>
</tbody>
</table>

Note: Source MRC. CH = Central Highlands, MD = Mekong Delta.

Table 4. Utilisation of Class 5 area for irrigation in dry and wet seasons

<table>
<thead>
<tr>
<th>Watershed area</th>
<th>Area of Class 5 land (million ha)</th>
<th>Area dry season irrigation (000 ha in 2000)</th>
<th>Current Utilisation (%)</th>
<th>Current use in wet season, for partial irrigation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>11.2</td>
<td>250</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>2.7</td>
<td>132</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>Thailand</td>
<td>12.2</td>
<td>156</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Viet Nam CH</td>
<td>0.4</td>
<td>37</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Viet Nam MD*</td>
<td>3.3</td>
<td>3,402</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>29.8</strong></td>
<td><strong>3,977</strong></td>
<td><strong>13.4</strong></td>
<td><strong>14</strong></td>
</tr>
</tbody>
</table>

Note: Source MRC. CH = Central Highlands, MD = Mekong Delta. * Includes double cropping in dry season
### Table 5a. Cropping areas in LMB ('000 ha) – upland crops

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Season</th>
<th>Rice</th>
<th>Maize</th>
<th>Cassava</th>
<th>Sugarcane</th>
<th>Mungbean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>2000</td>
<td>Wet</td>
<td>1,647</td>
<td>54</td>
<td>14</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>255</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>1999</td>
<td>Wet</td>
<td>631</td>
<td>41</td>
<td>13</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>87</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Thailand</td>
<td>1999</td>
<td>Wet</td>
<td>4,647</td>
<td>383</td>
<td>620</td>
<td>480</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>67</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Viet Nam CH</td>
<td>2000</td>
<td>Wet</td>
<td>181</td>
<td>87</td>
<td>38</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>51</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Viet Nam MD</td>
<td>2000</td>
<td>Wet</td>
<td>2,425</td>
<td>19</td>
<td>153</td>
<td>76</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dry</td>
<td>1,537</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note: CH = Central Highlands, MD = Mekong Delta.*

### Table 5c. Cropping areas in LMB ('000 ha) – fruit and industrial crops

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Fruit trees</th>
<th>Coffee</th>
<th>Vegetables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambodia</td>
<td>2000</td>
<td>164</td>
<td>little</td>
<td>32</td>
</tr>
<tr>
<td>Lao PDR</td>
<td>1999</td>
<td>0</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>Thailand</td>
<td>1999</td>
<td>381</td>
<td>0</td>
<td>39</td>
</tr>
<tr>
<td>Viet Nam CH</td>
<td>2000</td>
<td>0</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Viet Nam MD</td>
<td>2000</td>
<td>300</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*Note: CH = Central Highlands, MD = Mekong Delta.*
On the Mekong Delta, two dry season crops (April-August and November-March) are regularly cultivated in flood prone areas, although rice is grown in some fashion all year round where water is accessible and flooding not a problem (Figure 4). Traditional rain-fed rice varieties are now rarely planted in the Mekong Delta.

Other rain-fed crops include maize, sugarcane, mungbean, sesame, cassava, soybeans, peanuts and kenaf. Often, maize is cultivated on the more fertile soil along riverbanks; planting takes place early in the wet season and harvesting just prior to floods later in the year, usually in August or September. Sugarcane is also planted after the onset of monsoonal rains in May and harvested from November through to the following April.

Figure 2: Generalised cropping pattern for Lao PDR, Thailand and Cambodia

Harvesting mungbeans and sesame, sown on the opening rains, takes place prior to transplanting rice in July/August. Farmers in the uplands of Cambodia, Thailand and, to a lesser extent, the central highlands of Viet Nam and Lao PDR, sow soybeans later in the wet season (sometimes after mungbeans). Harvesting cassava, planted in well-drained soils during April/May takes place in December/January.

Cultivation of all upland and perennial crops is limited to topographies that do not
flood regularly. Only mungbeans and possibly peanuts receive supplemental irrigation during the wet season and approximately 129,000 ha of these two crops were grown in the LMB during 1999/2000 (Table 5). No more than 30,000 ha of these crops would have received supplemental irrigation.

Fully irrigated rice is cultivated extensively in the Mekong Delta (1.5-2 million ha) but little fully irrigated rice is grown elsewhere in the region. In 1999 Thailand grew 67,000 ha of dry season rice, the central highlands of Viet Nam grew 51,000 ha and 87,000 ha was grown in Lao PDR (Table 5a). In all probability, these areas receive all of their water requirements from irrigation. (Fully irrigated rice crops consume 8-10,000 m3/ha per crop). Less than half of the 255,000 ha of dry season rice grown in Cambodia are fully irrigated. The remainder is recession rice receiving supplemental irrigation at a rate of approximately 4,000 m3/ha.

Upland crops grown in the dry season include maize, mungbeans, sesame and sugarcane. Areas under irrigation are very small and not mentioned separately in all LMB countries’ agricultural statistics. The small areas of upland crops grown in Cambodia during the dry season (Table 5) are often sown in soils which have retained moisture or cultivated early in the wet season, receiving little if any irrigation water.

Each of the LMB countries has put aside significant areas for growing perennials including coffee and fruit trees plus vegetables. Coffee areas in Viet Nam, for example,
increased from 119,000 ha in 1990 to over 561,000 ha in 2000. Much of this was in the central highlands with 130,000 ha in one watershed in Dak Lak province alone (Giang et al 2000). Approximately 60% of Vietnamese coffee originates from an estimated 300,000 ha of trees in the central highlands (www.financialexpress.com/fe/daily). There are also 42,000 ha planted with coffee in Lao PDR.

Coffee plantations in eastern Cambodia were established during the 1990s, but the total area has not been estimated. Coffee is generally grown on fertile, porous soils and supplemental irrigation is required during the dry season, using groundwater sources. Water consumption estimates for coffee in Dak Lak ranged from 2000 m³/ha to 7,000 m³/ha (Nong Lam University staff, pers comm.) (See also Section 14.2). Fruit trees were grown on 381,000 ha of NE of Thailand in 1995, but the area may have expanded further since then (MAC, 2000).

In the Mekong Delta, the area under fruit trees is known to have expanded from 175,000 ha in 1995 to nearly 300,000 ha in 2002. This area is expected to increase to more than 500,000 ha in the near future as markets are established for the produce. OVPC (Overseas Project Corporation of Victoria) quote the area of fruit in Cambodia as being 164,000 ha (OVPV 2002). The central highlands of Viet Nam and Lao PDR may produce an extra 100,000 ha of fruit, increasing the total area of fruit in the LMB to approximately 950,000 ha. When fully irrigated, fruit in the Mekong Delta consumes 3,000-6,000 m³/ha during the dry season (NEDECO, 1991).

Total vegetable production in the LMB was approximately 120,000 ha in 2000 (Table 5c). Based on farmers’ experience in the Mekong Delta, consumption of water for vegetables on porous soils is about 2,500-3,500 m³/ha during the dry season.

4 Animal production

The total number of large animals in the LMB has increased significantly over recent years (MacLean, 1998, FAO, 2003). Buffalo numbers in Thailand and the Mekong Delta in Viet Nam have diminished slightly as farmers shift from using animal-drawn implements to machinery for crop cultivation. However, the increased number of cattle and pigs across the basin has offset this decline (Table 6).

The increase in large animal numbers is a reflection of improved crop production and of the general welfare of farmers. Higher rice grain yields for example, have resulted in associated increases in the quantity of stubble made available for grazing both cattle and buffaloes. Such dry season grazing areas are particularly prevalent in Thailand, Cambodia and Lao PDR. Pigs on the other hand are fed with rice bran, a by-product of milling. Increased grain production results in the support of a greater number of pigs, chickens and ducks.
Animal sales are a major source of income for subsistence farmers who see them as ‘banks’ for accumulation of wealth. Chickens are generally a source of protein for farmers, although there has been an expansion in the number of intensive chicken farms in the LMB over the past decade. Large animals consume approximately 50 litres of water per animal per day and there are approximately 24 million cattle, buffaloes and pigs in the LMB.

5 Fish and shrimp production

Fish caught from rice paddies are a major source of protein for farming populations in Cambodia, Lao PDR and NE Thailand. Studies by the Asian Institute of Technology estimated that fish collection from rain-fed rice fields in NE Thailand was in the range of 300-400 kg/household/year in a ‘good year’ and 100 kg/household/year in a ‘bad year’ (Gregory, 1997), thereby significantly surpassing chicken and other meats. Cambodians also catch fish living in rice fields (CIAP, 1998). Some researchers have estimated that the volume of fish caught in the paddy fields rivals that captured in the river system (Gregory pers comm.). The introduction of exotic herbivorous fish species to deeper fields in Cambodia and NE Thailand has also enhanced the supply of ‘paddy fish’. Small areas of freshwater aquaculture fish farms have also been installed in Lao PDR, NE Thailand and Cambodia.

The importance of the rice-fish combination to the overall health of farmers in all but the Mekong Delta in Viet Nam cannot be overstated and this type of food source needs protected from diminution through chemical abuse and poor land management (see section 10).

Fish production from irrigated rice paddies in the Mekong Delta is not significant and this is a reflection of shallower water depths, multiple cropping and overuse of pesticides. However, during the wet season fishers catch large quantities of fish in river ways, large canals and flooded areas. In addition, the Mekong Delta hosts a considerable fish aquaculture industry.

<table>
<thead>
<tr>
<th></th>
<th>Cattle</th>
<th>Buffaloes</th>
<th>Pigs</th>
</tr>
</thead>
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<tr>
<td>Cambodia</td>
<td>2.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Lao PDR</td>
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</tr>
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<td>1.2</td>
</tr>
<tr>
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<td>1.2</td>
</tr>
<tr>
<td>Viet Nam MD</td>
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<td>0.6</td>
<td>2.9</td>
</tr>
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<td><strong>7.5</strong></td>
<td><strong>9.0</strong></td>
</tr>
</tbody>
</table>

*Note: CH = Central Highlands, MD = Mekong Delta*
Fishery products currently provide half the protein for the Vietnamese population, and approximately 15% of these products come from inland fisheries in the Mekong Delta (Xuan and Matsui, 1998). In 1994, aquaculture production occupied 231,000 ha, of which fish occupied one-third and shrimp two-thirds. By 2000 the area under fisheries had increased to 445,000 ha (VSY, 2002), despite productivity dropping because of pollution (Do Van Xe, pers comm.). MRC-JICA, (2003) suggest that the area under fishponds on the Mekong Delta in 2001 was 511,760 ha, 392,200 ha of which was for shrimp culture and 119,560 ha for fresh water fish.

6 Why rice dominates agriculture in the LMB

Rice is the staple for a vast majority of the population in the LMB and has been so for thousands of years. It is likely to remain the staple for many years to come for reasons of: tradition; subsistence; land suitability; risk; ease of storage; and, marketability.

6.1 Tradition

The people of the LMB consume larger quantities of rice than those in other rice-eating countries. Annual consumption of milled rice ranges from 100 kg/head/year in Thailand to 162 kg/head/year in Lao PDR (Figure 4). For these people rice is an important element of daily life; most eat it three times a day, it feeds domestic animals and it plays a large part in religious ceremonies. As shown by the International Rice Research Institute (IRRI) in Figure 5, people are unlikely to make a significant shift to eating wheat, legumes or other staples until the average income exceeds $1,500 per

![Figure 4. Milled rice consumption in Asian countries](source: IRRI)
annum. Even at this income level, rice consumption will remain high enough to encourage farmers to cultivate rice for personal use.

### 6.2 Subsistence

The rural poor of Cambodia and Lao PDR are predominantly subsistence farmers. Surplus rice is exported from NE Thailand and the Mekong Delta, but in 2003, the majority of farmers in all four LMB countries still relied on producing sufficient rice to feed their families before looking at selling surplus production. Surplus grain can be stored and eaten if the price drops excessively.

### 6.3 Land and soil suitability

Waterlogging and inundation are common characteristics of the rain-fed lowland ecosystem. After a period of rainfall, the water table rises towards (waterlogging) and often above (inundation) the soil surface (Figure 6). Most plants cannot tolerate waterlogging and inundation. Rice, on the other hand, is a semi-aquatic plant, the shoots of which possess aerenchyma cells that transport oxygen from the leaves to the roots, allowing rice to grow under waterlogged soil conditions.

Many of the soils of the LMB are also acidic, have low levels of organic matter, low Cation Exchange Capacities (CECs), fix phosphorus and can possess toxic levels of aluminium under aerobic conditions (See section 9 for more details). These constraints to crop growth change within a few days of the soil flooding. Waterlogged soil quickly becomes anaerobic, inducing an increase in pH to a neutral level, toxic aluminium levels drop and phosphorus becomes available to the plant. In addition, many of the soils are sandy loams, which form a hard plough pan or seal at the surface preventing water penetration. This results in temporary waterlogging after initial rainfall or irrigation. Upland crops do not grow well in these soils, but they are suited for rice production.

### 6.4 Risk

Resource-poor farmers in SE Asia operate on low cash flows and carefully weigh the risks of adopting more costly farming practices. In addition, farmers are reluctant to risk their food security. Changing from rice to other crops entails investment in seed and other inputs, in addition to making capital-intensive modifications to the farm layout. Recent failed agricultural enterprises in the NE of Thailand include poor production, loss of markets or poor markets for basmati rice, castor seed, cashew nuts, cassava and milking cows, and that has emphasised the risk involved with newer systems. In the Mekong Delta, farmers can make considerable profit from brackish fish cultivation, but the investment is very high as are the risks of failure, especially in tough international markets.
6.5 Storage

Some harvested grain deteriorates rapidly under tropical conditions. Peanuts develop a potentially lethal aflatoxin if stored in humid conditions and soybeans lose their viability after a few months. Fruit may only be stored for days while some freshwater fish deteriorate within hours if not iced properly. Un-milled rice can be stored for months or years with little loss of quality.

6.6 Marketability

All the LMB countries have a well-developed rice market. Marketing of other products is much more difficult. After the harvest, traders are willing to buy any surplus rice either on or off the farm, while markets for other products are unreliable, especially for lower grade products. The insistence by traders for production of high quality grain often pre-empts many farmers from attempting to grow crops that initially appear to be of higher value.

7 Dry season vs. wet season cropping

The potential yield of any photosynthetic crop is dependent on plants receiving optimum amounts of energy, water, air (oxygen and carbon dioxide) and minerals.
They also need protection from excessive temperatures, pests and diseases, toxic effects and other growth retardants. In addition, traditional varieties require a change in day length for maturation.

### 7.1 Energy

The amount of sunshine the plant receives, particularly over the last two months of its growing cycle, determines the available energy for growth. Solar radiation figures are not commonly available in the LMB. In terms of energy supply, the number of hours of sunshine per day is more important than the day length. Figure 7 shows the relationship between day length in Phnom Penh and hours of sunshine in Ubon, NE Thailand and Omon, Mekong Delta. As shown in the figure, maximum solar radiation in LMB countries occurs during the dry season from February to May. After May, the solar radiation declines as cloud cover builds up for the monsoon season, reaching a low point in July and August at the peak of the rainy season. It then increases as the clouds clear.

### 7.2 Oxygen and Carbon Dioxide

Most crops suffer from a lack of oxygen when either their roots or leaf material become covered in water. As mentioned in section 6.3, rice is able to grow in waterlogged soil but like upland plants suffer if the whole plant is inundated with water for more than a couple of days. Dramatic reductions in yield will occur under these conditions. Carbon dioxide should be available to the leaves at all times for photosynthesis.

### 7.3 Water

Insufficient or excessive supply of water retards crop growth. As mentioned previously all crops suffer from oxygen depletion if flooded. Farmers in much of the Mekong Delta avoid inundation of their crops by planting immediately after the floods recede.
and harvesting before their onset. Short ‘mini droughts’ in the wet season are also a serious problem for rain-fed crops. However, 4 to 5 cm of supplementary irrigation during these periods can double yields or save complete loss of the crop. Irrigation in the dry season overcomes the risk of both flood and drought. The dry season is also the period of highest potential yield from an energy point of view.

7.4 Plant nutrition

Plants receive their nutrition from the soils via roots. Soil properties strongly influence the way in which inherent and applied nutrients reach the roots. Soil characteristics differ greatly across the LMB and will be discussed further in Section 9.

7.5 Temperature

Extreme temperatures, especially during the reproductive period, will also affect the development of crops. All SE Asian crops, including rice, are susceptible to hot days; temperatures in excess of 38 to 40°C have the potential to cause pollen damage, reducing grain yields. Cold may also retard growth in higher altitude, dry season crops in Lao PDR (Goeppert, pers comm) and in the central highlands of Viet Nam (Parkin pers comm.). In general, however, temperature extremes do not adversely affect either rice or upland crops in the LMB.

7.6 Pests and diseases

No crop can reach its potential yield when suffering from infestations of pests and diseases. Pests and diseases therefore need to be controlled.

7.7 Potential crop yields in the LM

Under ideal growing conditions, the yield potential of all crops in the LMB is higher.
during the dry season than in the wet season due the greater amount of sunshine received during this period (Nesbitt, 1997, Linquist and Sengxua, 2001). At the Cambodian Agricultural Research and Development Institute (CARDI) rice yields of the same variety are often more than 35% higher in the dry season under research conditions (Cambodia-IRRI-Australia Project, 1998/1999).

The potential yield for rice cultivated near Phnom Penh is estimated at being 9t/ha (IRRI, pers comm) and yields on small plots of irrigated, highly fertile soils in Southern provinces of Cambodia approach this figure. Reaching the potential yield in both seasons is dependent on diligently managing all factors affecting plant growth. Average dry season yields in Cambodia during 2002 were 3.1t/ha, well short of this target.

8 Rice cultivation techniques

Rice is grown in the LMB across a wide range of topographies and environments. Plants can be cultivated in different water depths (Figure 8) and times of the year using floodwater, direct rainfall or irrigation water to maximise grain yields.

8.1 Upland rice
In the mountainous areas, native rice varieties are dibbled into the hillsides in
combination with legumes, maize and tubers. This rice does not stand in ponded water and its yields are highly susceptible to weed competition plus drought. Selected varieties are tall and broad leafed to shade out weeds. After two or three cropping seasons, the soils become degraded and vigorous weed populations build up, forcing the farmers to rotate their fields. This is often termed shifting cultivation agriculture. Upland rice is sensitive to day length, ensuring the plants flower before the wet season draws to an end. Upland rice is never irrigated.

8.2 Rain-fed lowland rice

Lowland rice is more suited to grow in standing water than upland rice. Varieties are generally narrower leaved and tiller more profusely than upland rice, providing a higher yield potential. Traditional varieties are photoperiod sensitive and can be classified as being early, medium or late maturing. Early-maturing varieties (maturing November/December) are usually shorter in stature and grow in areas where the water depth does not exceed 20-30 cm. Medium duration (maturing December) varieties grow in deeper water environments. Harvesting of late maturing varieties takes place in December/January; these varieties grow in water depths often exceeding 50 cm.

Cultivation of non-photoperiod, early-maturing rice varieties for the rain-fed lowlands is becoming more popular in areas of improved water control. These crops may gain some supplemental irrigation and be harvested before the main traditional rain-fed crop is transplanted later in the wet season. Such early wet season crops are found mainly in Cambodia.

8.3 Deepwater/floating rice

Crops growing in water depths greater than 50 cm are often referred to as deepwater rice. If parts of the rice plant (including the main growing points) float on top of the water during peak water periods, they are called floating rice. In the LMB countries harvesting deep floating rice crops are generally takes place during January/February.

Deepwater and floating rice seed is broadcast at the beginning of the wet season to allow sufficient time for the plants to reach a physiological stage when they can elongate to keep pace with rising water levels. Many varieties can grow in excess of 30 cm per day and often have culm lengths of four to five metres. These crops suffer from drought and weed competition early in their life cycle and drought or excessive flash flooding later in the season. Farmers consider deepwater/floating rice as being a low-maintenance, but high-risk crop and most farmers have converted these areas to growing HYV recession rice or irrigated dry season crops.

8.4 Irrigated rice

The term ‘irrigated’ refers to all rice crops receiving off-field applications of water. This terminology often leads to confusion when figures are compared between one
country and another. For example, in Lao PDR, there are cases of rain-fed crops growing within irrigation schemes being included in datasets for irrigated rice (Goeppert, pers comm). Conversely, dry season crops are not all fully irrigated. Some dry season, recession rice crops on the edge of Tonle Sap Lake in Cambodia, for example, are not irrigated at all while other recession crops on gentler slopes further to the south are fully watered. Other potentially irrigable areas are only partially irrigated because of labour shortages or other constraints. Despite these problems, the areas of crops receiving supplemental water have increased in all LMB countries, particularly in recent years (see section 14 for more details).

Photoperiodicity has been bred out of high yielding rice, allowing crops to be cultivated at any time during the year. Non-photoperiod varieties are considered early maturing if they can be harvested before 120 days, medium maturing when they can be harvested between 120 and 150 days and late maturing at stages after 150 days. Apart from exceptional cases, farmers in the LMB seek early maturing rice varieties of less than 115 days for irrigation. New varieties can be harvested within 95 days of seeding but they are of low quality.

8.5 Transplanting vs. direct seeding

Early, medium and some late duration traditional rice varieties are transplanted in the
rain-fed lowlands of Cambodia, Lao PDR and Thailand. Nurseries growing seedlings take up 15-25% of the farm area. The farmer carefully tends the nursery until there is freestanding water in the main field. The optimum age for transplanting traditional varieties of seedlings is at four to five weeks. If insufficient rain falls in the early part of the wet season, seedlings often range in age from two to five months at transplanting, some of which may need pruning to prevent lodging (falling over). Transplanting shock sets back the development of all plants; especially those transplanted late or into poorly prepared main fields. Most HYV seedlings are transplanted at three to four weeks old.

Transplanting is a laborious method of growing rice. However, under typical conditions, the rice is transplanted into a flooded field that is virtually free of weeds and the weed-free environment persists until harvest. A weed-free crop is also possible if the seed is broadcast directly into a field possessing good water control. Broadcasting or ‘direct seeding’ is practised with all floating rice crops and approximately 30% of rain-fed and irrigated crops in Cambodia and NE Thailand. There is little direct seeded rain-fed rice in Lao PDR or the central highlands of Viet Nam. Transplanting has not been practised in the Mekong Delta of Viet Nam for two decades and all crops are now direct seeded.

Direct seeding can shorten the maturation period of HYVs by five to seven days, thereby reducing water consumption. In some locations, direct seeding increases the chance of a second crop being planted during the same year.

9 Soils

9.1 Soil types and distribution

The soils of the LMB have been classified over a number of years using different systems. In Lao PDR, for example, French, Russian, US and FAO classifications were used during the 20th century. In Cambodia, identification of most soils was initially based on a US map (Crocker, 1962) followed by the use of French and Vietnamese systems. The rice soils of Cambodia have also been classified on agronomic criteria (White et al, 1997). The US Soil Taxonomy system was used for soil mapping of Thailand and both Vietnamese and FAO/UNESCO systems in Viet Nam. All systems were utilised by the MRC in developing a basin wide land resources inventory for agricultural development using the FAO/UNESCO (FAO/UNESCO, 1988) soil classification system as a standard (MRC, 2002c).

Table 7 gives the major soil types in the LMB. Acrisols are the major soil type in terms of area and percentage of the LMB followed by cambisols. Gleysoils are common in the Mekong Delta along with a range of other soil groups. This table does not
accurately describe the soils in the areas that are potentially irrigable. When the Class 5 areas are examined, almost all of the Mekong Delta is classified as being suitable for irrigation: 65% of the Mekong watershed in Thailand and 72% of Cambodia (Table 8), but only 13% of the Lao PDR watershed as a whole and 11% of Viet Nam.

Almost 71% of the irrigable area in the NE of Thailand is classified as being occupied by acrisol soils, 50% in Lao PDR, 59% in Cambodia, 68% in the central highlands of Viet Nam and 2% in the delta of Viet Nam. (See Table 9).

MRC defines acrisols as soils that developed on old land surfaces of undulating topography in seasonally dry and humid tropical and monsoon climates (MRC, 2002c). They generally have a very thin layer of topsoil and possess low cation exchange capacity (CEC), are acidic in the subsoil, and are often saturated in aluminium to toxic levels when aerobic. Recurrent inputs of lime and fertiliser are needed for continuous cultivation and it is recommended that mechanical clearing of natural forests be avoided at all costs. Such soils would appear to be unsuited to agriculture except for the cultivation of acid-tolerant crops, such as cashews and pineapples. These soil characteristics do, however, change under flooded conditions.

Thirty-two percent of the soils in the potentially irrigable areas of Lao PDR are classified as being cambisols. These soils are characterised as having reasonable structural stability, high porosity, good water holding capacity and being moderately to highly fertile. Cambisols are thought to make good agricultural land and can be cultivated with a range of crops. According to the MRC land classification system, there is potentially 860,000 ha of this land in Lao PDR and 1.2 million ha in Cambodia. Only small areas are found in the other three watersheds. These soils appear to be ideally suited to growing upland crops including perennials, but may consume large quantities of water to keep the soil profile wet.

Gleysols are the most common soil type found in the Mekong Delta, taking up 75% of the potentially irrigable area (Table 9). These soils developed under long periods of waterlogging and are suitable for irrigated rice. For other arable cropping, horticulture or tree crops lowering of the water table by draining will be required. (MRC, 2002c). Some areas of these soils developed in brackish water sediments contain pyrite and may have turned into acid sulphate soils.

An extra 1.35 million ha of gleysol soils are found in Cambodia, generally on the Mekong Delta down towards the border with Viet Nam. Approximately 630,000 ha of gleysols are also found on flat areas in Thailand.

Small areas of fertile fluvisol soils are found along the edge of river systems in all five watersheds of the LMB. They are particularly prominent in the Mekong Delta. Such soils are productive for a wide range of dry land crops. As with gleysols, however,
they have already developed into acid sulphate soils if inundated with marine or brackish water for long periods of time.

Two hundred thousand (200,000) hectares each of Leptosol and Ferralsols soils are also found in Cambodia. Leptosols are usually associated with hilly and mountainous areas, which possess thin soil layers and are highly susceptible to erosion and, if cropped, drought. Ferralsols on the other hand are extremely weathered and possess high percentages of kaolinite clays. They are generally low in CECs, nutrient reserves and inactive applications of phosphorus. If carefully managed these soils are suitable for cultivation of oil palm, rubber and coffee, plus tree plantations or for grazing.

9.2 Soils and plant nutrition

The major soils covering the irrigable areas of Cambodia, Lao PDR, Thailand and the central highlands of Viet Nam generally possess ‘low natural fertility’ (Linquist and Sengxua, 2001) and are often “difficult to manage” (White et al, 1997). One author (Euroconsult, 1998) described the soils of NE Thailand as being “rated among the

<table>
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<th>Table 7. Soils of the LMB</th>
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</tr>
<tr>
<td>Acrisols</td>
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<td>Cambisols</td>
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<td>Gleysols</td>
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<tr>
<td>Fluvisols</td>
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<tr>
<td>Leptosols</td>
</tr>
<tr>
<td>Ferralsols</td>
</tr>
<tr>
<td>Other groups</td>
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<td>TOTAL</td>
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</table>

<table>
<thead>
<tr>
<th>Table 8. Percentage of area classified as suitable for irrigation</th>
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</thead>
<tbody>
<tr>
<td>Watershed</td>
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<td>Thailand</td>
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<td>Lao PDR</td>
</tr>
<tr>
<td>Viet Nam Central Highlands</td>
</tr>
<tr>
<td>Viet Nam Mekong Delta</td>
</tr>
</tbody>
</table>

poorest in South and SE Asia”. Untreated soils inherently result in low yields. Improvements are possible through the age-old practice of annually supplying organic matter to the fields in the form of manure or compost. The cultivation and incorporation of green manure crops also increases grain yields. However, to produce a
reasonable amount of biomass, it may be necessary to add phosphorus to the green manure crop beforehand. Most farmers are reluctant to do this.

Acrisol soils and some cambisols are invariably deficient in nitrogen, phosphorus and potassium and possibly sulphur, magnesium and boron in the sandier phases. Soil management recommendations for these soils usually include the application of fertilisers in small doses throughout the life of the crop. Prolonged flooding to overcome low pH, aluminium toxicity problems and the low CEC are also recommended for the cultivation of rice.

Nitrogen is the most limiting element for most lowland soils in the LMB and requires applications in quantities greater than other nutrients. For very 1000 kg of yield, the required uptake is about 15 kg (Linquist and Sengxua, 2001). Recommendations for rain-fed rice on sandy soils range from 50 kg of urea, 25 kg of di-ammonium phosphate (DAP) and 50 kg of potash to 125 kg of urea, 75 kg of DAP and 50 kg of potash per hectare (CIAP, 1998) and higher rates for heavier soils. Farmers rarely apply these rates of fertiliser because of the cash requirements for purchase and the high risk of ‘mini’ droughts occurring during the rainy season that would negate the value of the fertiliser. However, technology does exist for farmers to increase rice yields if farm-gate grain prices rise, particularly when the risk of drought can be eliminated. Increasing yields of upland crops on these soils is much more difficult.

On the Mekong Delta there are 1.1 million ha of fertile alluvial soils ideally suited for rice production (Xuan and Matsui, 1998). Fertiliser applications on these soils often exceed 150 kg/ha. In other parts of the delta there are problems of highly acidic, acid sulphate soils (1.6 million ha) mainly in the Plain of Reeds and Long Xuyen-Ha Tien quadrangle, and with saline soils along the coastal region (0.8 million ha). Soil management practices for each soil are vastly different. Farmers downstream of the acid sulphate soils also suffer problems of accessing acid irrigation water at the

Table 9. **MEC watershed classification systems – Class 5 soils in the LMB**

<table>
<thead>
<tr>
<th></th>
<th>Cambodia</th>
<th>Lao PDR</th>
<th>Thailand</th>
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<th>Viet Nam MD</th>
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<td>Area (ha10¹)</td>
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<td>0.05</td>
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<td><strong>12.18</strong></td>
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<td><strong>3.23</strong></td>
</tr>
</tbody>
</table>

*Note: CH = Central Highlands, MD = Mekong Delta*
beginning of the wet season when the area is flushed.

In conclusion, a vast majority of the soils in flat areas suited for irrigated agriculture in the LMB are infertile and acidic. Large areas of land are therefore unlikely to provide good economic returns to the cultivation of upland crops or perennials without substantial modifications to the soil. Such modifications would include an increase in the soil pH, increase in CEC and an improvement in soil fertility. Some of these problems can be overcome if the soils are anaerobic after being flooded for long periods. Under these conditions, the soil pH increases to neutral and phosphorus is released from the soil into a form more readily taken up by the plant. Applied nutrients are also more readily absorbed. Farmers may therefore continue to grow rice on these soils until upland crop technology is improved.

10  Fertiliser and Pesticide use

10.1  Fertiliser

The annual growth rate in the consumption of mineral fertiliser between 1989 and 1999 ranged between 3.9% (Cambodia) and 25.8% (Lao PDR) on a countrywide basis (MRC, 2002b). In these two countries, however, the consumption of fertiliser per ha in 1999 was very low at 2.1 and 8.5 kg/ha of agricultural land respectively. This compares with 100.1 kg/ha for all of Thailand and 263.2 kg/ha for Viet Nam. In Cambodia and Lao PDR much of the imported fertiliser was applied to vegetables and fruit trees, with the remainder applied to dry season rice production and upland crops.

Only 9.9% of all Lao farmers used chemical fertilisers according to an agricultural census conducted in 1998/99 and 14.8% only applied organic fertilisers (Nippon Koei, 2001). Most of the wet season rice in Lao PDR and Cambodia is still grown using traditional low input methods. These methods involve applying cow manure to the fields just prior to the onset of the monsoon rains and ploughing it into the soil during its first preparation. Applications are concentrated on the nursery fields (15-25% of the total area) to improve seedling quality. If they have reserves of cash to purchase it, some farmers will apply urea at panicle initiation. Farmers in NE Thailand also follow a similar practise; here inorganic fertiliser applications are much higher at 40-50 kg/ha on rice (JICA, 1993). In Viet Nam, use of inorganic fertilisers continues to rise as the farming practices intensify.

Composition of the applied fertilisers has progressively changed over the past 5-10 years in response to research results showing that most soils in the LMB are deficient in phosphorus and becoming increasingly deficient in potassium. Imbalanced fertiliser applications are particularly evident in the Mekong Delta where farmers apply nitrogen at 180-200 kg/ha (Nhan, 2003) but phosphorous and potassium are applied at very low dosages. In all countries where the farmers are better informed they apply phosphorous
and potassium fertilisers in addition to nitrogen. Targeted fertiliser applications will reduce pollution of the waterways, improve the efficiency of water usage and increase yields. Fertiliser losses to the waterways are not a serious problem in any of the LMB countries.

### 10.2 Pesticides

Pesticide consumption figures on a watershed basis are not available for LMB countries. In general though, use of pesticides in all LMB countries is low compared with western countries (www.fftc.agnet.org). In Lao PDR, the use of pesticides are restricted by the Lao Government. Herbicides are banned and insecticides plus fungicides are rarely used except on vegetables. Heong and Esculada (2000) estimated that pesticides were applied approximately 0.3 times per year in 2000. Government agriculture officials discuss Lao rice as being ‘purely organically grown’ and claim to receive a premium price on international markets because of it (Bountiep Chounthavong, pers comm.). As a result, water runoff from the paddies into the Mekong River possesses very low levels of pesticide residues.

Pesticide consumption in Thailand appears to be extremely high, the nation consuming over 47,000 tonnes of pesticide in 1995. However, farmers in NE Thailand farmers apply only 5% of the amount their counterparts in the central plain use and 10% of the usage of farmers in the north of the country (MAC, 2000). These farmers tend to follow low input practices in their wet season crops and applied only US$2.99 worth of pesticides per ha in 1998/99 (MAC, 2000). These levels of pesticides are unlikely to seriously pollute the waterways in NE Thailand. Fish production from the wet season rice paddies supplements the diet of most farmers in this watershed, indicating pollution of paddies is not causing problems.

In Cambodia, approximately 27% of wet season farmers and 59% of dry season farmers used pesticides on their rice in 1996 (Jahn et al, 1996) averaging US$1.23 and US$4.67 per ha in the wet and dry seasons respectively. These pesticides included insecticides, herbicides and chemicals used to kill rodents. Duuren et al., (2003) found that the use of pesticides increased towards the Viet Nam border where two thirds of the border farmers used pesticides compared with a quarter elsewhere. Wet season rice paddies are virtually pesticide free and pesticide applications rarely cause fish fatalities. Runoff from these paddies is reasonably clean of pesticide residues. However, dry season cropping, most of which is close to the border with Viet Nam, is subjected to an increasing number of pesticide applications, despite the efforts of Integrated Pest Management (IPM) practitioners.

Pesticide consumption is much higher in Viet Nam than in the other three LMB countries, especially in the intensively farmed Mekong Delta. Estimates of the number of applications range from 3.9 (Heong and Esculada, 2000) to 7.4 per crop.
(www.fftc.agnet.org) but rates are considered to be comparatively low at 1 kg/ha of active ingredient, compared with 11.8 kg/ha in Korea and 19.4 kg/ha in Japan. Farming systems specialists in Viet Nam are concerned at the level of pesticide use in the Mekong Delta and do not consider dry season rice paddies to be suitable for rice-fish production. Pesticide levels in the paddy water may also be high in more intensively farmed areas during the wet season, but the volume of water passing through parts of the Mekong Delta during this period flushes the system and fish farming is considered to be an option for farmers with deeper paddies.

Water quality close to the fish farming areas of the Mekong Delta is a serious concern for the industry. Drainage from fish and shrimp farms pollutes some waterways (Guttman, pers comm.). Such drainage contains toxins from intensive fish farm feeding activities and pesticide used to eliminate pests prior to filling the ponds. This problem will need to be addressed as fish farming activities in the Mekong Delta expand.

11 Farm mechanisation

Mechanising farming activities has the potential of increasing farm productivity and improving production. For example, replacing animal traction with engine-powered tractors will vastly speed up land preparation, thereby improving the timing of cropping patterns. A reduction in the time it takes to prepare the soil improves the chance of the plants taking advantage of higher solar energy months and avoiding droughts or floods. In some areas, it may also improve the number of crops that can be cultivated in one year allowing a higher percentage of agricultural land to be cropped.
However, agricultural equipment is expensive to purchase and operate. Adoption of tractor-powered land preparation, engine-driven water pumps, combine harvesting and mechanical threshing are therefore also dependent on the cost of labour and opportunity cost of time lost through the employment of slower practices. Labour costs and cropping intensities are vastly different in the four LMB countries; hence, farm mechanisation varies dramatically across the region.

In Lao PDR, there is no shortage of farm labour and little of the land is prepared by tractor. There is no combine harvesting of rice but mechanical threshing is increasing rapidly in the lowlands (Table 10). Tractors are almost exclusively used for land preparation in Thailand (because of the high labour rates) and the Mekong Delta of Viet Nam (to enhance opportunities for extra cropping and because grazing areas are in short supply). Combine harvesters are used extensively in the flatter provinces in the east and with decreasing frequency towards the undulating topography in the west of NE Thailand. Some farmers are now increasing paddy sizes in the NE of Thailand by land levelling to improve the prospects of mechanised farming.

Combine harvesting is either not economically feasible (in Cambodia and Lao PDR) or impractical (small paddy size in the Mekong Delta) in the other LMB countries. Some sugar crops are mechanically harvested in Thailand and this practice will increase with improved farm gate prices. Other upland crops are all harvested by hand. Most lowland rice in the LMB countries is machine threshed and machine milled. Upland crops of sesame, soybeans and dry peas may also be threshed and cleaned by machine.

In all LMB countries, engine-driven or electric pumps do most of the pumping of irrigation water. Hand or pedal-driven water pumps are still active in the poorer areas of Cambodia and Lao PDR, especially when supplementary water is supplied to rice seedling nurseries. However, this practice is in decline as the use of faster mechanical pumps spread across the countryside.

**12 Marketing and agro-processing**

Marketing of farm products is the main constraint to agricultural diversification in the LMB. In Cambodia and Lao PDR, access to markets is of primary importance to many of the rural population, while in Viet Nam and Thailand consistent demand of farm
production constrains wider adoption of non rice-based production.

In Lao PDR, the marketing system remains undeveloped because of the large subsistence component of farming community (Nippon Koei, 2001). Most surplus produce is sold at local markets and interregional distribution is limited. Consequently, regional market prices vary considerably. This is, in part, due to the poor road infrastructure and part from the lack of market information service. The State Foodstuff Company (SFC) has a commanding share of the market for paddy, storage facilities and rice mills, reducing competition. Market retail outlets are also managed by the central government, provincial or district administrations. Processing of agricultural products to add value is very limited.

A developing open market system in Cambodia is constrained by poor rural infrastructure and poor access to international markets. Primary, secondary and tertiary rural road construction continues to open up the way for farmers to access required inputs and transport any surplus production to markets (OPCV, 2002). Until recently, high-quality rice mills were not available in Cambodia and much of the surplus rice was exported as paddy (ACI, 2002). The country lacks extraction plants for its oil palm plantations and rubber is exported under licence from Viet Nam. Grading facilities do not exist to ensure the sale of quality products from the uplands. For these reasons, Cambodian farmers received well below world prices for their products and were unable to access the timely, correct information from markets so they could take advantage of price fluctuations.

Road and canal access to markets and market information is better in Viet Nam than Cambodia and Lao PDR. However, low prices and a lack of storage facilities continue to hamper agricultural diversification in the Mekong Delta and central highlands.

These issues are particularly prevalent with fruit and vegetable production (Dr Le Thi Thu Hong, pers comm.) where limited marketing information often leads to the sale of poor quality, low value products. Synchronous harvesting, coupled with a lack of processing, results in too much fresh fruit entering the market at any one time and it is also difficult to service the large community of small farm holders. Most farms in the Mekong Delta range in size from 0.1-2.0 ha, but the average is only 0.5 ha.

The NE of Thailand has an excellent network of roads and food processing is well developed. There are 11 sugar mills in the NE, plus a range of rice mills, cassava processing and vegetable oil extraction plants, plus canning factories. Despite the well-developed infrastructure and reasonable information and input services, farmers have not diversified significantly into non-rice crops. Rising production costs and static or falling prices are tending to deter farmers from investing heavily in these activities on infertile soils in the NE of Thailand.
13 Credit

Credit availability for farm activities varies across the four LMB countries. In Cambodia and Lao PDR, family, friends and traders provide the main source of funds to rural households. Interest rates are extremely high, ranging between 40 and 80% per annum. Generally, these loans are taken out for family emergencies and not to purchase inputs or provide funds for capital improvements to the farm. Village revolving funds are also popular in Lao PDR and state-owned banks provide funds for rural infrastructure, but not for farming activities. Cambodian agriculture is assisted by an NGO-established bank, which provides assistance to a small number of farmer recipients.

In Viet Nam, rural investment loans are available through the Viet Nam Bank for Agriculture and Government run (often foreign funded) poverty reduction programs (Dr Doung Van Vien, pers comm.). Bureaucratic procedures limit access to these funds (MRC, 1998).

Thailand has a well-established rural credit facility through the Bank of Agriculture and Agriculture Cooperatives. Interest rates for farmers vary from 7.5% pa for proven creditors to 13.5% pa for farmers having a low credit risk but possessing a good plan for repayment (www.baac.or.th/th-baac/interest/loanrate). Despite the low interest rates, the use of credit is low as NE Thai farmers prefer to borrow from family members for agriculture investment (JICA, 1993). Credit is not considered to be a constraint for rural investment in Thailand (Euroconsult, 1998).

14 Irrigation water

14.1 Surface water

In excess of 19,000 irrigation schemes had been installed in Lao PDR by 2000, servicing an area of 295,000 ha in the wet season and 197,000 ha in the dry season (Nippon Koei, 2001). The majority of schemes are of the traditional weir type in the mountainous northern and central regions, while pump irrigation is concentrated in the south. Overall, more than half of the irrigated area is pump irrigated (DOI, 2001). Not all schemes are fully utilised because of high operational costs and low returns (Nippon Koei Co Ltd, 2001). Government figures indicate that approximately 92,000 ha of rice were harvested from the dry season irrigated area in 2000. Pump irrigation costs have increased in recent months due to higher electricity prices, reducing demand even further. Consequently, the area under irrigation is not likely to expand rapidly in the near future without heavy government subsidisation.
In NE Thailand, more than 750,000 ha of land has infrastructure installed for irrigation (WUP-JICA, 2002). Approximately 32% of the area is under large-scale irrigation schemes, 19% medium, 27% small scale and 22% pumping schemes. These schemes are primarily used for providing supplementary irrigation to wet season crops. In the dry season, either insufficient water is available for crop cultivation or it is uneconomical to grow crops on the infertile soils. In 1998, Euroconsult (1998) considered that the cropping intensity during the dry season was only 10-15% of the irrigation area in the Lam Praplerng and Lam Pao schemes. Less than 50% of farmers planted any crop at all because high labour costs or a complete lack of available labour made cultivation impossible. Of the remaining 50%, few cropped the whole farm, with most planting high value crops like chilli and watermelon on small areas.

Thai Royal Irrigation Department figures for 2001 indicate that 116,492 ha (16%) of the irrigated area were planted. In 2002 this figure had was reduced to 94,789 ha (13%). Sixty four thousand (64,000) ha was planted to rice, 17,470 ha to upland crops, 5,294 ha to vegetables, 2,065 ha to sugar, 342 ha to fruit trees, 666 ha to other trees and 4,334 ha was dedicated to fishponds (RID crop figures).

RID planned to install 92 ha of irrigation infrastructure in the NE of Thailand in 2003/4. These schemes are mainly in the Mun and Chi catchments. Economic considerations are not seen as a constraint to their installation as it is Government policy to provide as many opportunities as possible for population of NE Thailand to remain residents of the NE.

Cambodia has 946 operating irrigation systems that can service 256,120 ha of the two million ha wet season cultivated area. In the dry season, rice is grown on 255,000 ha and 143,490 ha of this can receive irrigation water from irrigation schemes. Hence, only 12% of the wet season rice is irrigable, the remainder being rain-fed. Just over half of the dry season crop is irrigated, the remainder being recession rice receiving supplementary irrigation from manually operated and diesel-driven pumps. Very few of the irrigation schemes are capable of irrigating all year round.

Most dry season rice is cultivated on land flooded during the wet season. Crops are transplanted as the floods recede in a similar manner to recession rice. They are then either gravity fed from upstream dams or water is pumped from irrigation canals. The latter is a common method south of Phnom Penh where most land is only five to seven metres above sea level and high lift pumps are unnecessary.

Fully irrigated crops receive approximately 10,000 m3/ha. Some irrigation engineers in Cambodia consider recession rice receives approximately 4,000 m3/ha of irrigated water (G. Himmel, pers comm.).

The number of surface water irrigation schemes in the central highlands of Viet Nam is small compared with other parts of Viet Nam. Schemes are found along the river and
on valley floors irrigating approximately 50,400 ha of rice in all of the central highlands in 2001 (VSY, 2002). This compares with the 300,000 ha of coffee irrigated from groundwater sources (see 14.2 below).

A JICA (2003) estimate that approximately 1,479,000 ha of agricultural land was irrigated in the Mekong Delta of Viet Nam during 2001. This figure compares closely with those provided by Vietnamese research institutes. Estimates are that about 300,000 ha grows three crops of rice per year, 1,080,000 ha is double cropped and 200,000 ha is cultivated to upland crops (Tanh, pers comm.) Water is extracted from 2,500km of natural rivers and creeks and 3,000 km of canals (Binh, 2002). Some of this water is directed into acid sulphate soils in the Plain of Reeds and Long Xuyen–Ha Tien quadrangle causing problems with severely acidic water being flushed along the same canals into more productive areas at the onset of monsoon rains.

Pump costs are high towards the north of the delta where flooded water levels may need to be reduced to cultivate two crops of rice during the dry season. In the fresh water alluvial zone it is possible to harvest 2-3 crops per year using high tides to irrigate paddy fields and low tides for their drainage. The use of tides for crop irrigation is more difficult along the coastal region and the Ca Mau penisular. These areas are becoming increasingly used for fish farming. Saltwater incursion is a serious problem in parts of the Mekong Delta during the months of January-May when river flow rates are at their minimum.

14.2 Groundwater

Pattanee et al (2002) estimated that 75% of domestic water in Thailand was obtained from groundwater resources, serving 35 million people in villages and urban areas. The only region in Thailand irrigating crops from groundwater is in the north of the country. Groundwater studies suggest freshwater can be found among the numerous saline aquifers in NE Thailand, but there is not the volume for wide-scale irrigated agriculture (RID pers comm.).

Good freshwater aquifers are located along the mountainous region of Lao PDR and some of these are used to water the 42,000 ha of coffee located in the area (Bountiep Chounthavong, pers comm.). A small amount of extra water is used for domestic consumption.

Groundwater sources are often overextended in the support coffee production in the central highlands of Viet Nam. In 1989, for example, 11,357 ha of coffee was reported destroyed by drought (www.financialexpress.com/fe/daily). Regardless of problems, the area under coffee has increased dramatically over recent years in response to population resettlement programs. There are currently about 300,000 ha of coffee grown in the central highlands.
Recharge of aquifers is generally slow and farmers are known to dig horizontally from the base of wells to extract more water. Although groundwater levels are known to rise and fall with the season, water tables are declining over time (Dr Trinh Truong Giang, pers comm.). Water in these areas is applied to coffee over the dry season at approximately 50 mm each nine days (SRMP, 1999). This rate is equal to 65 cm (6,500 m$^3$) per ha. Groundwater is also used for domestic purposes.

The Mekong Delta possesses six aquifers with depths ranging from 15 m-75 m and 275 m-400 m. Water reserves are considered to be large (Haskoning, 2000), but to exploit them care must be taken with location and drilling because much of the water is either brackish or saline and recharge characteristics are poorly understood. Water in the lower aquifers is 20,000-30,000 years old and not recharged from local rainfall, causing concern for its misuse. Some bores to the medium depth aquifers were artesian or sub-artesian sources 10-20 years ago, but are already suffering from overuse with water levels dropping rapidly. In part of the delta, shallow groundwater aquifers have been exhausted. Water levels are thought to have declined through both abstractions and by the extensive surface drainage system constructed during the 1990s.

The only major areas on the Mekong Delta consuming groundwater for agricultural production are located between and along the Bassac and Mekong rivers. Although the drawdown is significant during the dry season, when these areas take their water directly from the river, floods recharge the shallow aquifers during the wet season.

Extensive shallow groundwater reserves are known to exist around the Tonle Sap Lake and beside the Bassac and Mekong Rivers in Cambodia. Water levels in shallow wells
and tube wells follow the river height for distances up to 30km each side of the Bassac River (CIAP, 1999) indicating the aquifers are constantly being recharged. Farmers in the provinces of Kandal, Takeo, Svey Rieng and Prey Veng have taken advantage of these reserves by installing cheap shallow tube wells to irrigate one to two ha of dry season crop. Unfortunately, the recharge rate is slow and in some intensively irrigated areas farmers run short of water during peak periods.

Dry season rice production in Prey Veng, and Takeo using groundwater during 2001 covered an area of between 5,000 and 10,000 ha (CARDI, pers comm.), up from zero in 1995. JICA (1999), estimated wells in the quaternary age aquifers of Svey Rieng, Prey Veng and southern Kandal can yield 500-800 m$^3$ per day without causing adverse effects on the entire groundwater basin. Such pump rates would irrigate four to six ha of rice per well. The potential for irrigation from groundwater from these aquifers is therefore quite high if properly regulated to ensure minimal drawdown. There is insufficient recharge capacity in the aquifers for large-scale irrigation projects.

15 Water consumption by agriculture in the LMB

15.1 Consumption as a percentage of renewable resources

Mekong river water is utilised for irrigation, hydropower generation, domestic and industrial purposes. Much of the water emerging from hydropower stations is also consumed downstream for irrigation, domestic and industrial purposes. Irrigated agriculture is responsible for 80-90% of water abstractions from the basin (FAO from MRC, 2002b) and is utilised in the form of receding floodwater storage, diversion of water from streams and from ground water sources.

On a nationwide basis, the LMB countries do not fully utilise their renewable water resources. Renewable water resources are equal to the total precipitation in the country minus evapotranspiration. ‘Irrigation water requirements’ are an estimate of the amount of water required to water crops while ‘water withdrawn for agriculture’ is the amount used. The ratio between estimated irrigation water requirements and the actual withdrawal is usually referred to as ‘irrigation efficiency’. Cambodia and Lao PDR use only 1% of their total renewable water resources for agriculture while Viet Nam and Thailand use 5% and 20% respectively (Table 11).

Based on these figures, an average Mekong river flow of 460 km$^3$ each year can service the irrigation requirements of all LMB countries 11-fold. An annual Mekong river flow can also service approximately 64 million ha of fully irrigated rice, based on a consumption of 10,000 m$^3$/ha (one metre of water) per crop. This compares with the 1999/2000 area of two million ha of dry season cropping in LMB watersheds (Table 5).
There is no shortage of water in the Mekong River to service agriculture in its watersheds if all water is captured and redistributed when required. This is, of course, not the case, with a majority of water flowing through to the ocean during the wet season when crops receive most of their water requirements directly from rainfall. Water shortages may occur (especially in the Mekong Delta) during the months of February to May when water flows in the Mekong River are at their lowest (see Figure 9). Crop irrigation is the major consumer (see sections 3, 4 and 5).

### 15.2 Crop water requirements

Irrigation water consumption for crops can be estimated reasonably accurately by employing the following FAO (www.fao.org/ag/agl/aglw/aquastat/water/) model:

\[
IWR = Kc \times ETo - P - S
\]

Where:
- \(IWR\) is the irrigation water requirement needed to satisfy crop water demand
- \(Kc\) is a coefficient varying with crop type and growth stage
- \(ETo\) is the reference evapotranspiration depending on climate factors
- \(P\) is precipitation
- \(S\) is the change in soil moisture from the previous month.

Total water consumption in any cropped area will involve measurements of rainfall, evaporation, soil type, loss of water from canals and other structures, crop type, stage of crop growth, area of each crop, planting time, the irrigation method employed and crop duration plus a range of other factors. The Mekong River Commission’s Water Utilisation Programme (WUP) has excellent programs for calculating water consumption of various cropping patterns in the Mekong River Delta. Abstraction rates vary considerably across different ecosystems.

### 15.3 Water requirements for cultivated rice

Rice cultivation is the largest consumer of irrigation water in the LMB. NEDECO
(1991) calculated water requirements on the Mekong Delta in February averaged 0.8 l/sec/ha for rice (2000 m³/ha/month), upland crops at 0.6 l/sec/ha and perennial crops at 0.4 l/sec/ha. These rates are included in Figure 10 to examine water requirements of the major cropping systems used in the Mekong Delta. Other rates appearing in the literature for LMB countries include 10,000 m³ per irrigated rice crop (Cambodia), 12,000 m³ per irrigated rice crop (Thailand), 1 l/sec/ha (8,294 m³ for 120-day rice crop) (Mekong Delta), 19,600 m³/year/ha (Mekong Delta).

As mentioned in section 15.2, consumption depends on a number of factors. Because it prefers flooded conditions, rice has a high water consumption compared with other crops. In the publication Rice Today (April, 2003. Vo 2 No 1), IRRI says that traditional irrigation techniques consume five cubic metres of water to grow one kilogram of rice. Dry-land crops produce the same amount of grain for one cubic metre and irrigated rice in Australia and the United States consumes approximately 1.2 m³/kg. If it is assumed that 10,000 m³ of water was used to produce one hectare of dry season rice in the LMB during 2000, then average rice grain production used 3.3 m³, 2.5 m³, 3.0 m³ and 2.0 m³ of water to produce 1 kg of grain for Cambodia, Lao PDR, Thailand, and the Mekong Delta in Vietnam respectively.

15.4 Irrigated upland and perennial crop water consumption

Upland crops including vegetables and perennials consume less water than rice. Commonly used crop factors are as follows: rice, 1.15; bananas, 0.9; maize, 0.75; groundnuts, 0.7; citrus, 0.65, melons, 0.65; vegetables, 0.65; soybeans, 0.65 (FAO 1998). Therefore, for water conservation purposes it would appear advantageous for farmers to grow more upland crops and less rice. As mentioned in sections 6.0, 8.0 and 9.0 there is only a limited amount of land in the LMB suitable for upland crops and vegetables in terms of soil nutrition and vulnerability to water logging and/or inundation. Cultivation of these crops needs to be restricted to either the higher, more fertile, well-drained soil types during the wet season or be fully irrigated during the dry season. Many rice paddies levelled to maximise the production of rice grain may need considerable earthworks in the form of raised beds or field gradients in order to cultivate such crops.

Irrigated perennial crops include fruit trees, bananas and sugarcane in the lowlands and coffee and pepper in the mountainous regions. Fruit trees are occasionally irrigated using a permanently flooded ditch and dyke system (which is very expensive in terms of water consumption), irrigated by canal and ditches (intermediate water use), by pump and hose (low water use) or via trickle irrigation techniques (very efficient water utilisation). NEDECO, (1991) allowed 3,628 m³/ha for perennial cultivation in the Mekong Delta over the four-month critical period between February and May. In addition to direct abstractions from canals, the trees take up water from the shallow aquifers. As the perennial cropping intensity increases
Figure 9. Average irrigation water requirements for main cropping systems in the Mekong Delta, Viet Nam
on the land suitable for upland and perennial crops, more irrigation may be required as the water table is lowered below the deep-rooted trees.

In the mountainous regions of Lao PDR and Viet Nam, cultivated coffee and pepper are replacing natural non-irrigated forest. Both cultivated crops need to be well watered during the months of January to March to induce flowering. Rates of 6,500 m$^3$/ha/year are abstracted from groundwater sources in the central highlands of Viet Nam (SRMP, 1999). Similar abstractions are expected from Lao and Cambodian coffee plantations.

### 15.5 Water consumption by animals and fisheries

Water consumption by animals is estimated at 50 litres per day (l/day) per head of cattle, buffalo and pig. Poultry and ducks consume a lesser amount. The estimated 24 million large animals in the LMB each consume 1.5 m$^3$/per month (36 million m$^3$/month for total herd). Over the four-month critical period (equal to one rice crop) consumption by animals is equal to 14,400 ha of fully irrigated rice at 10,000 m$^3$/ha. Small areas of freshwater fish farms have been installed in Cambodia, Lao PDR and NE Thailand. However, the major aquaculture consumers of Mekong River water are the fish and shrimp farms on the Mekong Delta.

Freshwater fishponds are topped up to replace lateral and evaporative losses. Pond water is also changed before installing new fish batches. JICA (2003) estimated consumption of irrigation water in the Mekong Delta fishponds was at 34,000 m$^3$/ha across the 119,560 ha pond area in 2001.

Fresh water is used in coastal shrimp culture ponds to top up water levels to prevent excessive build up of salt in the ponds. Addition of fresh water also reduces disease (Guttman, pers comm.). JICA (2003) estimates the area of coastal shrimp culture in the Mekong Delta during 2001 was 392,200 ha and each hectare consumed 4,600 m$^3$ of fresh water per year. Some effluent is from these ponds is discharged into irrigation canals causing problems when the water is re-used by neighbouring enterprises (Guttman, pers comm.). Evaporation losses from open ponds are high.

### 15.6 Overall water consumption in the LMB

Fifty nine percent of the LMB watershed area remains uncleared (Table 1) and, agronomically, natural forest may still be the largest consumer of water in the basin. The forest receives all of its required water from annual rainfall and by tapping residual soil moisture plus water from shallow aquifers during the dry season. Overall water consumption decreases in land denuded of forest and cultivated with annuals, but there will be an accompanying change in seasonal flows into the mainstream and possible long-term climate change effects. Cultivated perennials consume more water in the dry season than annuals, especially if irrigated. Only small areas of perennial
crops are grown in the LMB compared with annuals (Table 5), although the area occupied by fruit trees has not been properly documented.

Abstractions from the Mekong River in the LMB are not limited during the wet season when flow levels are high. However, there may be constraints on water use during the dry season, especially in regional drought years. A rough calculation of water consumption by agricultural activities during the critical months of February to May for the LMB is presented in Table 12.

The crop areas in this table are based on those documented in Table 5. To complete the table it was presumed that all fully irrigated dry season rice used water at a rate of 0.8 l/sec/month and that crops were not fully cultivated each month (Figure 9). Different water utilisation rates were assigned to other crops, animals and fishing activities (Table 13).

Figures presented in Table 12 do not accurately reflect consumption as indicated by the figures provided by the Viet Nam Sub Institute of Water Resources Planning (WRP) for the Mekong Delta region of Viet Nam (Table 12). The same institute also estimated the rate of consumption in the first 10 days of February 1998 as around 782.2 m³/sec for agriculture, 2.25 m³/sec for animal production, 24.7 m³/sec for fisheries, 14.6 m³/sec for forestry, 13.5 m³/sec from canals, 123.7 m³/sec from general evaporation and 5.2 m³/sec from waste land.

More detailed measurements need to be made for each activity to refine the calculations. However, the indicative consumption rates in Tables 2, 3, 4 and 12 plus the cropping patterns presented in Figures 3, 4 and 10 demonstrate there is considerable latitude for maximising the effectiveness of abstractions from the Mekong river for agricultural production. These are discussed in Section 15.7. It is also interesting to note that, using the assumptions in Tables 12 and 13, agricultural activities in the Mekong Delta of Viet Nam consumed twice as much water over the four-month period compared with the other four watersheds together.

15.7 Strategies to reduce the consumption of irrigation water

Strategies for limiting the consumption of water used for agricultural purposes in the LMB include timing of cropping systems to avoid high water consumption during the critically low water flow months and by reducing the amount of water each crop uses. The lowest abstraction rates from the Mekong River occur when crops are rain-fed and not irrigated. Most rain-fed upland crops are grown in well-drained areas that are susceptible to neither flooding nor waterlogging. Rain-fed rice may be cultivated in areas susceptible to waterlogging and some low level flooding. Harvesting these crops (see Figure 3) takes place before the critical months of February-May. Water consumption by rain-fed crops can be decreased by improving their water use
efficiency (efficiency of the crop to use water in producing total dry matter), increasing the varietal harvest index (percentage of dry matter harvested as grain) and reducing in the amount of transpired water (by selecting improved varieties). Ensuring the crops are properly fertilised will assist this process (see section 9.2 for more details).

Soils can also be improved for the longer term. For example, some farmers in NE Thailand can afford to place bentonite to improve fertiliser and water availability for sugar cane production (Floether, pers comm). Land levelling reduces water losses and
increases yields for rain-fed rice (CIAP, 1999) and installing raised beds reduces waterlogging and inundation for upland crops (CIAP, 1997). Other practices that decrease overall water use include the reduction of maturation period of HYV rice varieties through direct seeding (CARDI, 2000), employment of minimum tillage methods (Floether, pers comm.) to retain soil moisture and synchronous planting to reduce pest damage to plants. Mechanisation gives farmers time to plan their activities.

Effective water conservation techniques that can be employed during the wet season to reduce water losses include the installation of efficient water distribution systems, soil compaction of canals and fields to reduce percolation, land levelling, direct seeding, soil fertility improvement and the use of shorter duration varieties.

Supplemental watering of rain-fed crops through partial irrigation usually results in abstractions during the high river flow period. Local ‘mini droughts’ of a month or so are generally not reflected in the Mekong river height. In some cases, fields in Cambodia, Lao PDR and Thailand may suffer flooding at one end of the field and be drought affected at the other. Redistributing this water will not affect the overall accessibility of river water at critical periods. Supplemental irrigation during the wet season is especially effective with potentially high yielding crops. Recession rice is planted into flooded soil and may or may not receive supplemental irrigation.

In Cambodia, sowing crops takes place as early as November and harvested in February. Harvesting crops sown later may extend into the ‘critical period’ and these definitely require irrigation for reasonable yields. The cultivation of shorter duration rices during this period may avoid the need to irrigate later than February. Techniques that allow crop planting in deep floodwater at the beginning of the season will also extend the irrigation free period. Upland crops requiring less water cannot replace recession rice unless the fields are drained beforehand. LMB soils, in general, do not have residual soil moisture properties suitable for growing non-irrigated crops if the crop cycle commences when the surface of the soil is dry.
The planting of the winter-spring rice crops on the Mekong Delta as early as possible also takes advantage of flooded soil conditions. Some farmers sow directly into 20-50 cm of floodwater when turbidity drops sufficiently for sunlight to penetrate to the seed. In October through to December, irrigation of these crops uses water taken from the Mekong while the level of the river is high; the crops, however, are still able to benefit from high energy levels in January-February, a period when they mature (see section 7 for details). At the end of the flood season, some paddy fields may need pumping to reduce water levels before they are in a suitable condition for planting rice. This pumping increases crop costs.

Early dry-season crops are the most likely to achieve yields close to their potential because they mature in periods when energy derived from sunlight is at its greatest. There should also be sufficient water and the crop can take advantage of new silt deposits from the wet season floods. Direct seeding early maturing crops in levelled, properly fertilised, fields should maximise the potential gained from each unit of water. Delaying the cultivation of the second crop (summer-autumn) will reduce water consumption at the beginning of the season and utilise rainfall later in the year.

However, delaying planting may result in flooding of some second crops in the late season. Replacing rice with uplands for later planting is problematic because of the threat of flooding at the end of the season (July to September) – see section 6.3 for details. Growing faster maturing, improved, varieties may reduce crop duration and water use efficiency. Percolation losses can also be limited through the selection of impervious soils for cultivation and by compacting soils to reduce losses.

Short (105-115 days) and very short (95-104 day) duration rice varieties are cultivated in localities where it is possible to grow three crops of rice in one year (or five crops in two years). At these sites, periods of deep flood do not reduce the total growing season and the soils are sufficiently fertile to permit continuous cropping. In some locations, upland crops may replace one of the rice crops, thereby reducing water usage. Suitable sites need to be properly drained and some land forming may also be necessary to achieve good yields sites. High crop factors (1.15 for rice and 0.7 for many upland crops) will result in the consumption of a large volume of water when any crop is cultivated and irrigated between February and May. In the Mekong Delta, the promise of high yields due to the high energy levels radiating on the crops currently offsets the possibility of water shortages. In future though, large water savings will occur if areas currently growing three crops per annum reduce their cropping intensity.

As mentioned, upland crops do not like waterlogged soils or inundation. Their cultivation is therefore restricted to the dry season and/or to well-drained soils. Planting of any fully irrigated upland crop should therefore be avoided when water shortages are predicted. If grown at all, fast maturing crops should be planted early and
harvested before February. Perennial crops also use a considerable amount of water year-round for survival and growth. As data presented in Table 12 shows, any further expansion in the area of fruit trees or coffee will place greater pressure on diminishing water levels during the dry season.

The rate of fresh water usage in fish and shrimp ponds is debatable and needs proper measurement. However, replenishing evaporation losses from shrimp ponds with seawater is impracticable if salt concentration is a problem. Fresh water additions to ponds should therefore at least equal the difference between pan evaporation rates of 75 cm and precipitation rates of 25 cm over the four-month ‘critical period’ (i.e. 50cm). In addition, freshwater ponds need filling and occasional flushing. Aquaculture consumes large volumes of water and the expanding areas of ponds in the LMB, especially on the Mekong Delta, will result in a high demand on Mekong River water. Water losses from the ponds can be minimised by ensuring percolation losses from the ponds are low and through the employment of evaporation loss reduction techniques.

16 Water quality in the LMB

Potential water quality problems for LMB farming activities include excessive salt, pesticides, nutrients from fertiliser and other pollutants, acid water and solids.

Saline water is a problem for farmers using surface water from salt affected soils in NE Thailand and for periods of the year when salt intrusions occur from the ocean up the river and canal systems in the Mekong Delta (MRC-JICA, 2003). The incidence of rising salt can be reduced by lowering the water table through reafforestation of small hills in the flat plains in the NE of Thailand. The Thai Government is promoting this activity in some areas. Saltwater intrusions in the Mekong Delta are a regular occurrence in the dry season and are expected to intrude further up the river as abstractions increase for irrigation, domestic and industrial purposes (Xuan and Matsui, 1998).

Many aquifers in NE Thailand and the Mekong Delta are saline and their water may need mixing with fresh water before it can be used for agricultural purposes. Much of the groundwater in all LMB watersheds may also contain high levels of iron, calcium and sometimes arsenic, reducing its usefulness for domestic purposes.

Nutrient pollution from misuse of chemical fertiliser is not a big problem for the Mekong River and is unlikely to occur unless use of fertiliser expands significantly above the current low application rates. The low exchangeable cation percentages in LMB soils will facilitate the rapid transfer of nutrients to the river if excessive fertiliser is applied.
Pesticide application rates are very low in Cambodia, Lao PDR and NE Thailand and chemicals from these countries are not expected to significantly pollute Mekong River water. Spillages occasionally occur in the Mekong Delta canals but the effects remain local. Pollution of pesticides and other toxic waste from fishponds has wider implications in the coastal and Ca Mao regions of the Mekong Delta where diseases are thought to spread from farm to farm through the re-use of polluted irrigation canal water. Preventing the spread of infection and toxic effects in these areas may require installing drainage systems. Localised pollution from human occupation has also led to high biological oxygen demands in some areas (WUP-JICA, 2002).

Flushing of acid sulphate areas in the Plain of Reeds and Long Xuyen quadrangle region of the Mekong Delta has caused problems for farms further along the canals system through the presence of excessive acidity, aluminium and iron in the water. This problem is expected to continue for 20 or 30 more years (Nghiem Dinh Tanh, pers comm).

Since the introduction of agriculture along the Mekong River approximately 4,000 years ago (in NE Thailand) and more recently on the delta itself (over past 300 years ago) farmers have relied on the annual silt deposits to fertilise their soil for crop cultivation. Recent information (Halcrow, 2003) indicates that denudation of forests in Lao PDR, Thailand and Viet Nam has increased river sediment loads. These are partly offset by the construction of dams along the river and tributaries withholding some of the load. A reduction in the river silt load will increase the reliance of Mekong River agricultural irrigators on chemical fertilisers to maintain crop yields.

17 Government policies and potential for agricultural development in LMB watersheds

Governments of each of the four countries making up the LMB have different approaches to the development of their respective Mekong watersheds.

Cambodia

The Cambodian Government aims to transform agriculture into a driving force to achieve higher national economic growth and reduce the incidence of rural poverty (OPCV, 2002). Major objectives of a public investment plan are to:

- maintain a liberal market-orientated trade environment deregulate the exportation of agricultural products by removing unnecessary internal regulatory constraints and introducing effective licensing and registration develop agricultural standards by encouraging investment in appropriate infrastructure and facilities for post harvest handling, storage and processing and, establish appropriate commercial laws and institutional arrangements for efficient and cost effective market transactions.
The government will continue to invest in research and extension services to enhance the development of technologies and their transfer to farmers. Strengthening of infrastructure plays a major role in government policy. In the current five-year plan, emphasis is on the construction of a road network into rural areas. These roads have opened up farming land in many parts of Cambodia and settlement of tracts of land in the east of the country will rapidly follow. Future national focus is on the installation of irrigation facilities to reduce the effects of drought and flood. In order to do this, suitable sites need to be located and approved.

Economically viable sites have been difficult to find in the past because of the flat nature of Cambodia and the poor soils. However, over 10 million ha of gentle sloping and flat land (Class 4 and 5) are unutilised for agriculture (Tables 2 and 3), almost eight million ha of which is classified as irrigable (Class 5). Most (59%) of the area is on poor acrisol soils diminishing the economic viability of developing this land for irrigated agriculture. The remaining soils may be located in areas suited to irrigation if water is available. A majority of undeveloped land is to the east of Cambodia which is poorly serviced by rivers, but now that the area is being opened up for development, further investigations as to their commercial viability may be warranted.

**Lao PDR**

Lao government’s policy for national development is based on the 5th Five-Year Socio-economic Development Plan for 2001-2005. National agricultural development priorities include: ensuring food security; stabilising/reducing the area of shifting cultivation; commodity production support; irrigation development; agriculture and forestry research; and, human resources development (Nippon Koei Co, 2001).

Development of the lowlands is primarily through improving and diversifying farming techniques while the uplands will follow community based management practices.

Data presented in Tables 2 and 3 show Lao PDR has over 3.5 million ha of gently sloping (Class 4) and potentially flat (Class 5) land which has not been developed for agricultural purposes. More than one third of the flatter land (Table 9) is composed of reasonably fertile soils (cambisol and fluvisols), which would be more economical to irrigate than acrisols if water was available. As 35% of the Mekong water originates from Lao PDR, there is considerable potential for such projects being implemented along river tributaries. Abstractions would increase accordingly. The implications on water availability and seasonal flows after clearing the forest need further study.

**Thailand**

The Thai Government’s policies delivered to the National Assembly on 26 February 2001 emphasised the support the government would give to farmers to reform their
debts, promote the practice of mixed agriculture and optimise the use of idle land. In the development of domestic markets, the Government has undertaken to promote a ‘one village, one product’ philosophy, support improved marketing systems, strengthen cooperatives and improve its contribution to agricultural research. It also envisages that competitiveness on the international markets will be improved by increasing investment in agro-processing and upgrading quality standards. Government departments continue to promote development in the NE of Thailand to ensure its population has opportunities for advancement. Infrastructure investment continues.

Most of the Class 4 and 5 areas in NE of Thailand are already developed for agriculture that is presently based on risk-averse, low-input, low-yield technology, having evolved in response to erratic rainfall and infertile soils. Agro-processing is mainly associated with post-harvest processing such as sugar mills, rice mills, cassava processing plants, vegetable oil extraction and a few canning plants. Although irrigation offers potential for intensive cropping, so far, few crops other than rice have been found with market prospects and returns to justify farmers’ investment in irrigation. Rising production costs and static or falling farm prices expect to “squeeze” farmers further (Euroconsult, 1998). Most observers conclude that, for the foreseeable future, agriculture in the NE will consist of the following components:

- Wet season rain-fed and irrigated rice in the most productive lower paddy fields.
- Dry season rice on better soils in some irrigation schemes that have sufficient water.
- Sugarcane production in the higher rainfall areas and on the better soils and on some irrigation schemes within transport range of sugar mills.
- Maize production in better soils on higher rainfall areas.
- Intensive fruit and vegetable production under irrigation.
- Extensive cattle production on areas formerly cropped with cassava and other rain-fed crops.
- Intensive cattle, pig and poultry feeding enterprises.
- Tree crops such as rubber cashew, mango, eucalypts bamboo, neem and teak in areas formerly cropped with cassava and other rain-fed crops.
- Irrigation schemes to make more efficient use of water in the dry season with higher value crops.

17.1 Viet Nam

Viet Nam’s agricultural policy has strongly influenced the shape of agriculture in both the central highlands and on the Mekong Delta. In the central highlands, heavy investment in the uplands has witnessed a large degree of immigration to the central highland provinces resulting in a rapid expansion in the agricultural area. More recently perennial coffee and pepper have replaced annual crops (Giang et al. 2000).
Heavy government investment in the construction of canals and dykes in the Mekong Delta to control flooding and for irrigation has been curtailed. No new canals are being constructed, just improvements to existing structures. Farmers are being encouraged by Government policy to diversify their farming systems to stabilise farm income. The Mekong Delta has been divided into a number of zones based on production costs and financial returns to facilitate planning. Different systems are then promoted in each zone. For example, farmers are not encouraged to grow rice in the South West corner of the delta where the benefit cost ratios for rice are low. They are encouraged to convert their farms into shrimp production.

The Government would like to see a reduction of 200,000 ha in the area used for rice and an increase in the cultivation of other crops. It assists improvements in the quality of crops by subsidising seed production programs for rice, vegetables and upland crops. The Government also provides a floor price for paddy to help the poorer farmers.

Rice production is being encouraged in the centre of the delta where there is fertile soil and yields can average 6 tonnes/ha in the dry season and 4 tonnes/ha in the wet season. Adjacent to this zone, new settlements have been established on landfill provided by the Government to allow residents to remain near their farms during the wet season when the area is normally abandoned because of annual floods. An Giang province invested US$22 million in 2003 for 83 new settlements to house 13,155 households.

Government officials envisage farmers will now invest in cages to raise fish during the flood season rather than leave the province to find work elsewhere. Acid sulphate affected areas will continue to be used for melaleuca forests or growing green
pineapples. Other government policies that assist farmers include low taxes on agricultural produce, the provision of funding for agricultural research and extension, education for rural children and subsidies on infrastructure construction.

The Mekong Delta has considerable potential for increasing agricultural productivity with continued Government and private investment. It is envisaged that the delta will remain a rice-based agriculture system with an increased level of aquaculture and fruit tree production (Dr Do Van Xe, pers comm.). It is projected that animal production will increase as export-based pork and chicken enterprises expand in number. Grain from upland crops is needed to supply animal feed requirements.

18 Research on water used for agriculture in the Lower Mekong Basin (LMB)

Returns to investment in agricultural research in LMB countries are considerable (Cox and Chhay, 2000) and all governments provide sufficient resources for the establishment of research centres into agronomy, forestry, animal husbandry and veterinary science plus fisheries. Traditional lines of investigation based on commodity and discipline are generally followed although the level of activity in each is closely correlated with GDP per capita and population size of the country.

Overall farm productivity may also be investigated through farming systems research divisions, but generally, these divisions may fall under a particular commodity. For example, research at the Cambodian Agricultural Research and Development Institute (CARDI) contains programs on plant breeding, agronomy and farming systems, soil and water science, plant protection, agricultural engineering and socio-economics. At the Southern Fruit Research Institute (SOFRI) in Viet Nam research divisions include biotechnology, fruit breeding, plant protection, horticulture, post harvest technology, fruit marketing and a separate division for vegetable research. In the latter institute, fruit and vegetable production are often viewed as a minor portion of the overall farming system.

Research on water used for agriculture concentrates on salt water tolerance for various crops (fruit trees at SOFRI, rice at the Cuu Long Delta Rice Research Institute CLRRI and NE Thailand research centres) drought tolerance (rice at CARDI and Ubon Research Station in NE Thailand), acid water tolerance (CLRRI, SOFRI), flood tolerance (CLRRI, Ubon, CARDI), soil water retention (soil science divisions of most centres) and rice fish culture (CARDI and Thai institutes). General research on water use also includes studies on tidal irrigation, ground water resources, flood diversion, salinity prevention, maintenance of fresh water reserves plus other sectors.

Little or no research is conducted in reducing the amount of water used for crops by improving water use efficiencies, reducing percolation rates from fields and canals or improving soil water retention. In general, this type of research is restricted to
shortening crop cycles through plant breeding and crop selection, farm mechanisation and cropping systems research. The small amount of work in NE Thailand to improve fertiliser retention by slotting bentonite below crop roots has successfully increased crop yields. Similar research to improve the utilisation of water will pay long-term dividends for farmers in all parts of the LMB.

19 Risk and adoption of new technologies

Risk aversion is of primary importance to most LMB farmers who either survive on a subsistence level or are very low-income earners. Rice farmers are generally the poorest farmers in the LMB. Trade in rice grain is minimal in Lao PDR and Cambodia where most farmers barely survive on their annual production (Figure 10). Although rice is the major export of the Mekong Delta in Viet Nam and from the NE of Thailand, farmer’s income is quite small.

When the farm-gate price was set at US$0.08 per kilogram for paddy, the total rice production in NE Thailand was valued at US$38 per person, the Mekong Delta of Viet Nam, US$80, Cambodia US$27 and Lao PDR US$34. Considering most of the population of the LMB countries are engaged in agriculture, total income from rice production is extremely small.

Crop returns from farms vary considerably across the region. Sareth, (2002) found that gross family income (Gross income minus cash and in-kind costs) equalled US$131 per ha in Takeo province for a single crop and US$119/ha/crop for double cropping.
When farmer labour is charged to the budget, rice production was a loss making exercise with net incomes of minus US$103 and minus US$74 for single and double cropping respectively. Other crop budget summaries are presented in Tables 14 and 15 indicating the low level of rice farm income across the LMB. It is common for farmers to supplement their farm incomes by seeking labouring jobs nearby or in the cities.

Farmers wishing to change farming systems to improve their income need to take into consideration a number of factors. These include land and soil suitability for the new system, climate variations, location to markets, marketability of commodity, commodity price, storage, potential yields, pests and diseases, capital costs, labour availability, recurrent costs plus a range of other issues concerning knowledge, technical support and finance. Most importantly, the farmer must be able to make allowances for the risk of these parameters changing before, during or after implementing new systems.

Local research can do little to control prices on international markets for agricultural commodities. However, technologies can be developed to improve the quality of products available to the market place, agro-processing, storage lifetimes and the control of pests. New technologies may also help alleviate climate problems through

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Table 14. Crop budgets for NE Thailand, 1996/97

<table>
<thead>
<tr>
<th>Cultivation type</th>
<th>Rice Rain-fed</th>
<th>Rice Irrigated</th>
<th>Rice Irrigated</th>
<th>Sweet Corn Irrigated</th>
<th>Canning Tomatoes Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
<td>Wet</td>
<td>Wet Dry</td>
<td>Dry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variety</td>
<td>Local HYV</td>
<td>HYV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating costs US$/ha</td>
<td>98.4</td>
<td>118.0</td>
<td>110.0</td>
<td>128.1</td>
<td>260.0</td>
</tr>
<tr>
<td>Cash gross income US$/ha</td>
<td>96.9</td>
<td>119.7</td>
<td>130.1</td>
<td>279.2</td>
<td>713.1</td>
</tr>
<tr>
<td>Net crop income US$/ha</td>
<td>-44.0</td>
<td>-49.0</td>
<td>21.0</td>
<td>73.0</td>
<td>604.0</td>
</tr>
</tbody>
</table>

Notes: Source Euroconsult (1998). Net crop income assumes labour cost (hired or family) of US$2.5 per day

Table 15. Structure of average income of the farm households in 1992 in Cai Be, Tien Giang province and Thot Not, province, Viet Nam (% of total income)

<table>
<thead>
<tr>
<th>Household livelihood</th>
<th>Rice</th>
<th>Aquaculture</th>
<th>Animal Husbandry</th>
<th>Orchards/upland crops</th>
<th>Other income</th>
<th>Total income US$h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cai Be</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mono rice</td>
<td>63</td>
<td>0</td>
<td>4</td>
<td>4</td>
<td>29</td>
<td>376</td>
</tr>
<tr>
<td>Rice fish</td>
<td>57</td>
<td>13</td>
<td>12</td>
<td>8</td>
<td>10</td>
<td>633</td>
</tr>
<tr>
<td>Thot Not</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mono rice</td>
<td>54</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>46</td>
<td>1,170</td>
</tr>
<tr>
<td>Rice fish</td>
<td>43</td>
<td>36</td>
<td>5</td>
<td>6</td>
<td>10</td>
<td>1,234</td>
</tr>
</tbody>
</table>

Notes: Source Xuan and Mastui (1998)
A few risks farmers face in the LMB that have direct or indirect impact on the water use from the Mekong River are presented in Table 16. Research into many of these issues is ongoing and significant advances have been made in resolving some problems. If demand for commodities changes and prices increase, a different set of risks may emerge and this will also influence research efforts. Until then, farming system diversification should continue within the boundaries discussed in section 17.
20 Conclusions

Rice cultivation dominates agriculture in the LMB for a number of physical, biological, social and economic reasons. The crop, however, does consume a large amount of water, and the area under cultivation may need to be reduced if irrigation water shortages become more serious. Average consumption across the LMB is close to 2.7 m$^3$/kg of grain whereas soybeans use 56% of this amount.

Constraints to overcome before suitable areas can be cultivated with non-rice crops include the low prices earned for other crops, poor storage facilities and quality control, poor marketing, pests, water quality and water stresses, a lack of labour and capital, poor plant nutrition and a lack of technical knowledge by farmers. Farmers are also risk averse when replacing their guaranteed family food source with a cash crop.

In the foreseeable future agriculture in NE Thailand is projected to consist mainly of low-input, low-risk, wet season, rain-fed and irrigated rice production in the lowlands. Sugar cane, maize and fruit production and tree crops will occupy higher, less flood-prone areas along with extensive cattle production. Water use is not projected to increase greatly until soil improvement techniques are extended or food prices rise.

Lao agriculture is less developed than in Thailand and there is room for expansion in rain-fed and irrigated agriculture in the large areas of flat and gently sloping hills.

Thirty five percent of the total Mekong river flow originates from Lao PDR and there are over 850,000 ha of potentially good soils on flatter land that may be irrigated. The remaining 1.37 million ha of less fertile acrisols may also be developed for less intensive agricultural activities.

Cambodia possesses 10 million ha of gently sloping and flat land that is currently unutilised for agriculture. Abstractions from the Mekong River will increase when this land is developed further, especially if the country continues to construct roads and provide other infrastructure to isolated areas. Although 59% of the Class 5 land in Cambodia is composed of infertile acrisols, there is still considerable potential for production increases on these and other soil types.

The aquifer system in the central highlands of Viet Nam appears to be overextended and new sources of water may be required to support an expanding coffee industry. The area of potentially irrigable flat land is quite small and composed of mainly infertile soil types. Room for expansion in the level of water abstractions from the Mekong River therefore appears to be quite small.

The Mekong Delta already faces water constraints during the dry season. Farming system proposals for different eco-regions of the delta will result in a reduction in the
area of rice grown, but there is potential for increasing abstractions during the dry
season if farmers significantly expand the area under upland crops, perennials and fish
ponds.

Farmers in the LMB remain poor due to the low prices received for the major
agricultural commodities. Rationalisation of the industry to achieve greater economies
of scale is unlikely to occur in the foreseeable future because of the basic subsistence
nature of a majority of farms. Already, farmers receive cash supplements from off farm
activities to support their incomes. Farmers are therefore unlikely to pay for irrigation
water. On-farm overuse or miss use of water may however, be reduced through the
promotion of water saving techniques and the introduction of crops with higher water
use efficiencies. This needs to be accompanied by a reduction in the risk farmers face
in the adoption of new crops and practices.

River water pollution currently appears to be a minor problem in all watersheds
excepting the Mekong Delta close to aquaculture enterprises. Management of all
additives entering the river needs to be monitored, especially in the Mekong Delta.

21 Discussion and recommendations

Crop production in watersheds of the Mekong river is limited by flooding, poor soils,
poor access to markets, high input costs, pests and diseases and insufficient labour.
However, by far the greatest constraint to production overall is a lack of soil water.

Drought is a serious problem for crops in Lao PDR, NE Thailand, Cambodia and parts
of Viet Nam. If water were not a limiting factor in the rice paddies and upland areas of
these countries, yields would initially increase by at least 50% without extra inputs and
possibly double with applications of inorganic fertiliser. There is more than enough
water in the Mekong River to provide the current watersheds’ requirements year round. Excepting for the Mekong Delta in Viet Nam, water distribution systems are limited, but abstractions are increasing as riparian governments promote agricultural production by subsidising the installation of irrigation infrastructure.

Planning for efficient utilisation of available water is therefore essential to equitably spread the benefits of this resource for the majority of the watersheds’ inhabitants. Projecting the consumption of water by agricultural activities is a difficult task considering the poor database on which the calculations are to be based. Short, medium and long-term approaches are therefore needed to overcome these planning constraints.

**Short-term activities**

Short-term studies are required to improve the accuracy of calculating current water consumption rates. Recommended studies include carefully reviewing the government stated areas and yields of all crops cultivated in the LMB. The amount of water consumed by representative farming systems should then be physically measured.

1. **Crop areas**

Agricultural production is responsible for 80-90% of water abstractions, most of which is for crop production. Poor crop area measurements therefore restrict the degree of accuracy modellers with which can predict water consumption and the annual distribution of that consumption. More detail of when and where the crops are established will assist predictive measurements. For example, some crops are planted on non-irrigable land that cannot receive supplemental irrigation water, while other areas are planted within irrigation systems that can receive water if necessary. The question is what percentage of these areas receives irrigation water and what percentage of the irrigation area is cropped?

This approach should be taken for rice, which has been shown to consume a large volume of water, and for upland annual crops and perennials, which are potentially large consumers during the critically low river level months of February-May.

2. **Agricultural water consumption**

Current crop water consumption estimates are made on predictive FAO models. These should be checked by physically measuring the water used by different crops, cropping systems and farming systems. It is possible to do this by installing simple measuring devices (V notches) at water inlet and outlet points on a field or farm level. Further measurements can be made by surveying typical farms to calculate the amount and frequency of water applied to coffee, pepper, fruit trees, freshwater fish ponds and shrimp ponds.
Medium term activities

Further expansion in the use of Mekong River water for agricultural purposes is constrained by a range of physical, economic and social factors. Sites must be identified and closely researched before installation of infrastructure. Economic viability from a farmer’s perspective will rely on low cost access to water on fertile soils that have the potential for providing high crop yields. As illustrated in NE Thailand, farmers will not invest capital into cultivating crops when the rates of return are low. Inputs and markets must also be accessible and labour must be available.

3. Water availability and suitable soils

Successful irrigation projects possess both suitable reservoir sites and command fertile soils. Many of the irrigation schemes in NE Thailand are small and do not water good quality soils. Farmers are reluctant to cultivate large areas of these soils in the dry season because of low yields. In Cambodia, much of the land in highly populated areas is flat and dam structures often flood similar areas of land to what is irrigated. Now that land to the east of the country is being opened up with new roads, it may be possible to identify land that is both flat, fertile and has a nearby water source. When these areas are identified, future water consumption can be estimated.

Cambodia possesses over 11 million ha of Class 5 land that can be investigated for this purpose. Lao PDR has a higher degree of available water and 2.73 million ha of potentially suitable land, half of which is on reasonable fertile soils. The central highlands of Viet Nam are composed mainly of poor soils and the Mekong Delta is already fully cultivated. Therefore, identification of potential new sites from which abstractions from the Mekong River may increase should be concentrated on Cambodia and Lao PDR.

In addition to having high fertility, good irrigation soils should also possess low percolation rates. Little is known of percolation rates of many irrigation schemes in the LMB, making water consumption estimates difficult to calculate. These can be surveyed easily and included in soil suitability maps.

4. Farm economics

Problems of low yields may be, in part, offset by a high availability of labour and close proximity to markets for purchase of inputs and sale of product. This is the case in NE Thailand, where dry season farmers tend to grow high-value crops such as watermelons and chillies if nearby markets exist for the product. There is a need to conduct a closer examination of crop budgets in each of the watersheds. Based on the results of these studies, researchers will have a better understanding of the financial thresholds farmers need to cross before they take up the opportunities for expanding production of various crops in underused irrigation areas. The study results may also assist in the identification of new irrigation projects.
5. **Labour availability and productivity at the farm level.**

Crop budgets and the economics of various farming systems often depend on labour being available for farm activities. A study on seasonal labour constraints will help identify preferences of different farming systems.

6. **Risk**

Most farmers in the LMB are poor and suffer considerably when farming ventures fail, particularly when their family food source is put at risk. Risks faced by irrigated crop farmers include water supply breakdowns, floods, water salinity etc. Risk-coping strategies need to be taken into consideration in studies on farm economics and labour availability mentioned above.

7. **Marketing**

Access to markets is an essential component of successful farming enterprises. A short study of the markets for agricultural products in each riparian country will assist the identification of potentially new crop cultivation areas.

**Long-term activities**

8. **Water use efficiencies and irrigation efficiencies**

Water use efficiency (WUE) is the efficiency of the crop to use water in producing dry matter. WUEs are different for a range of crops and for varieties within species. It may be possible to decrease the use of irrigation water by growing particular crops and selecting the correct varieties possessing high WUEs. Research to select crop and variety type with high WUEs is long term but worthwhile in locations where water shortages are severe. Irrigation efficiency is the ratio between estimated water requirements and actual water withdrawal. Johl (1997) estimated water losses from the scheme he worked on were as follows:

<p>| | |</p>
<table>
<thead>
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</thead>
<tbody>
<tr>
<td>Main canals</td>
<td>15-20%</td>
</tr>
<tr>
<td>Major and minor distributaries</td>
<td>6-8%</td>
</tr>
<tr>
<td>Field canals</td>
<td>20-22%</td>
</tr>
<tr>
<td>Irrigation distribution, deep percolation</td>
<td>25-27%</td>
</tr>
<tr>
<td>Utilisation by crops</td>
<td>28-29%</td>
</tr>
</tbody>
</table>

FAO suggests that the irrigation efficiency in Lao PDR, Thailand and Cambodia is similar at 30% and slightly higher for Viet Nam (from Table 11). Large water savings are therefore possible if these losses can be reduced. Indicative irrigation efficiencies need to be determined for major irrigation areas in the LMB and strategies suggested to increase efficiencies. These are long-term studies.
9. **Potential crop yields**

Little is known of the yield potential of the wide range of crops grown in the LMB. For this reason, it is difficult for agronomists to correctly predict responses for nutrient applications. The LMB spans across 12.5 degrees of latitude and yield potentials may need to be calculated for various environments.

10. **Waterway pollution**

Fertiliser and pesticide application rates on agricultural land in much of the LMB appear very low and losses from the field are predicted to be small. However, most of the soils in the region possess low CECs and therefore may not retain nutrients and other applied chemical products. Levels of these pollutants entering canals should be monitored. Legislating acceptable wastewater discharge contents from fish and shrimp ponds may also be required to protect the environment.

11. **Groundwater availability for agriculture**

The existence of groundwater in LMB countries has been studied to various degrees. The extent to which this water is available to agriculture is poorly understood. A report summarising the results of previous studies and speculating on the area of irrigation aquifers can support is required. This will assist planning for aquifer utilisation for both upland crops and irrigation of the lowlands.
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