A Water-Poverty Accounting Framework: Analyzing the Water-Poverty Link

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Abstract: *Water has been identified as a crucial resource for all life, production, and development, while a lack of access to water has been linked to poverty. Governments and donors have declared a desire to use water more efficiently, equitably, and environmentally sustainability. These different links and objectives touch upon many disciplines and people working in and/or dependent on water: economists, sociologists, engineers, politicians, decision-makers, and other stakeholders. There exist tools to describe how water is used in a physical sense and where it is available. There are also methods to examine the multidimensional aspects of poverty. However, until now there has been no tool to effectively examine the availability of water and its use toward meeting social goals as opposed to physical goals. This paper offers a framework for such an analysis. The Water-Poverty Accounting Framework presented here allows an analyst to effectively see how water is being used to meet different social goals such as hygiene, sanitation, irrigated production for poor farmers, and environmental demands. More importantly, this framework demonstrates the implications for (re)allocations of water when meeting social goals is deemed desirable.*

Keywords: *Water, poverty, irrigation, development targets, management, water management*

Introduction

It has been widely acknowledged that water is a critical element of poverty in its many dimensions (World Bank, 1993; Asian Development Bank, 2000; World Commission on Dams, 2000; WSSCC, 2000). In response, there is a growing call to recognize guaranteed access to water for life (sanitation, hygiene, and subsistence production). This is in addition to the call to allocate water to the environment in quantities sufficient to guarantee a sustainable future for the resource. There is wide recognition that water is becoming an increasingly scarce resource, forcing users to become more efficient in utilizing water. One rarely sees a study or project on water that fails to cite the triad of efficiency, equity, and environmental sustainability. It is surprising then, that there is a glaring lack of an effective tool to simultaneously address the many elements of water management and water-related poverty. This paper offers a framework for Water-Poverty Accounting that helps to fill this gap.

The Water-Poverty Accounting Framework (WPAF) developed in this paper unites the many different dimensions of the management and use of water with specific regard to poverty alleviation. The WPAF works within the constraints of available water at any given level: from household to basin. Water use is accounted for according to its various uses, such as environment, industry, agriculture, sanitation, etc., but within the context of achieving certain social goals. The developed framework expands on the water accounting framework developed by IWMI researchers that accounts for water by the way it is used (Molden, 1997). The methodology developed here accounts for the way available water is used to meet social goals, particularly poverty alleviation.

Water and Poverty

Water and poverty are topics of great interest among development specialists, agencies, and donors. Unfortunately, the problem is often limited to discussions of semantics rather than to practical approaches to effectively address the problem. The problem is much simpler than is normally recognized. The poor experience a certain set of conditions characterized as a lack of access to resources and opportunities. The most common indicator used to analyze a person's access to resources and opportunities is income where low incomes are associated with severely restricted access to resources and opportunities. However, access to and use of resources is not always for income generating production. There are several quality-of-life aspects that cannot be measured by income.

It is at this point that the water-poverty problem normally becomes complicated. An attempt is made to precisely define which bundle of conditions forms that critical condition of poverty. The water specialist has their job made easier by the fact that they are limited to those conditions which can be directly impacted by access to water. One simply has to examine from a household level how water can impact any single condition. There are two elements to this problem: 1. water managers' ability to deliver water where it is needed, and 2. water users' ability to effectively use the delivered water. The critical question is one of how access to water can positively impact any given condition of poverty. Conditions attributed to poverty that are directly linked to water include water for agricultural production, drinking water, sanitation, and hygiene.

Once individual impacts are identified and measured, then it is a matter of seeing how available water can be used to meet these different requirements. If water is scarce, then priorities must be set as not all needs can be simultaneously met. "New" water can be introduced through efficiency gains, recycling, or importing water either through physical means or "virtual" means such as the importation of products that require water for their production. An underlying premise of this paper is that water for basic human needs will be guaranteed. It should be pointed out that this does not mean delivery will be guaranteed, but that a quantity of water shall be reserved for each person's basic needs within a given area. Delivery of water will necessarily involve financial costs that will need to be accounted for in order to be sustainable.

Water-Poverty and Basic Human Needs

In this paper, water-related human basic needs are defined as uses of water needed to sustain life and livelihoods. These uses include water for hygiene, drinking water, sanitation, growing crops to meet nutritional requirements, and growing crops to generate income equal to the poverty line. If these basic human needs are to be satisfied for all, then each person would need to have access to some certain quantity of water. If a person does not have access to enough water, then they are experiencing a dimension of water-related poverty. The implication is that for a fully allocated basin without access to other water sources, any net increase in population will increase the amount of water required to meet basic human needs. This would also dilute existing water rights by the additional amount required to meet the increased basic human needs. This idea is illustrated in the simple example shown in Figure 1 where the solid horizontal line at the bottom of the shaded region represents the current division of water allocations to either “basic human needs” or “other uses.” The dotted line represents the allocation required to adequately meet the increase in basic human needs.

In order to meet basic human needs, water must be reallocated from the “other uses” sector. This water must come from existing uses either by canceling existing uses or by realizing greater use efficiency. Alternatively, water can also be obtained by increasing efficiency in use within the basic human needs sector. This water can be derived from irrigation as used by poor farmers.

The Water-Poverty Accounting Framework (WPAF)

The overall framework for Water-Poverty Accounting is shown in Figure 2. The framework is expanded to include all possible demands and social goals for which water can be used. The key terms and classifications of the WPAF are explained below:

Inflow: The total amount of water flowing into the basin from surface water, groundwater, precipitation, and changes in storage. Also added to this category are the net flows from equivalents for food exports and imports. Finally, net flows from all inter-basin transfers are accounted for here.

Absolute water-poverty needs: Needs where the quantity of water necessary to meet those needs is fixed. These amounts are essential to life and health and, as such, apply to all people regardless of their income level.

Relative water-poverty needs: Needs where the quantity of water necessary to meet those needs is variable, as income can be earned from alternative, non-water using activities. This amount does not apply to all people. This is because the focus is on the impact of water use to generate income.

Target quantities: Target quantities are quantities of water required to meet different goals or demands. These are what the water managers and policy makers would like to achieve based on stated goals and demands.

Hygiene and Drinking water: Water needed to meeting demand for drinking water and hygiene. As a basic human need, this quantity applies to all people whether they are income poor or not.

Sanitation: Water needed to meet sanitation demands. As a basic human need, this quantity applies to all people whether they are income poor or not. This may be zero if non-water sanitation methods are used.

Production for nutrition: This refers to water used to grow crops to fulfill minimum nutritional requirements. As a basic human need, this quantity applies to all people whether they are income poor or not. The target level within a given basin would correspond to that amount of water needed to grow a nutritionally adequate diet. The actual amount would be based upon current food consumption patterns within the basin. A second-best calculation can be based on an aggregate estimate of this amount. In Figure 2, water for production for nutrition refers to water required to grow enough food to meet basic nutritional requirements. The quantity of water required to meet this use is fixed for a specific area and population given a set of crops, yields, management, and efficiency. (It is acknowledged here that specific determination of nutritional needs of people is not exact and, therefore, determining the amount of water needed to produce required food will also be difficult.) If the water allocated to this use is inadequate, then options include importing of water through physical diversions, importing of water in the form of "virtual water" through food imports, or by reallocating water from other uses. This quantity is termed "nutritional water" in the case study which follows.

Unadjusted irrigation for household income: Water used to produce crop output where the price of the crop multiplied by the output quantity equals the poverty line. This quantity refers entirely to income poverty. This quantity is not reported directly, but is used to calculate other amounts.

Irrigation for household income: This relates to the right or need to engage in an income generating livelihood. Water used to meet demands of farmers growing crops where the crop is not consumed, but sold; however, income is still below the poverty line. The target level of water for this use would be that amount of water need to increase crop production above the level of a nutritionally adequate diet to a level so that crop values are equivalent to the poverty line. The actual amount of water for this use could be calculated from aggregate amounts of water used to grow crops that equaled in value the poverty level for the whole population. Ideally this calculation would equal the actual water amounts used by farmers for irrigation. That is, a disaggregated approach would be used so that the total amount for this use is reduced when there are farmers who do not receive enough water to grow sufficient crops. This quantity is termed "irrigation: income" in the case study.

This use is for production in surplus of that required to meet subsistence needs and can include gardens, local 'home' plots that are not part of an irrigation system, and peri-urban plots. This use can be flexible if farmers leave farming due to economic transformation and the farmland is retired. If the farm is transferred to a non-poor farmer, then the use is no longer needed to meet poverty alleviation goals. This implies that it may be preferable to reallocate water to different uses, such as water for nutritional requirements where population increases, or to counteract the detrimental effects of climate change or natural disasters.

Irrigation for commercial agriculture*:* This component is water used to meet the demands for growing crops where the crops are neither used for subsistence nor for income gained beneath the poverty line. The target level can be defined as current use levels or projected future use levels. This is labeled "Irrigation: Commercial" in the case study results. The actual level calculated would be based on irrigation that actually occurs to grow crops above the poverty level as determined from a more disaggregated approach.

The previous three definitions all relate to irrigation and are depicted in Figure 3. Irrigation for household income and water for production for consumption refer to different dimensions of poverty. Together, these two definitions are equal to the unadjusted irrigation for household income, which refers exclusively to income poverty.

Non-poverty needs*:* This is water used to meet non-poverty demands. These demands include industry, navigation, tourism, recreation, and hydropower. Placing all these uses into one category is not to say that their uses are simple or unimportant. They are placed under one category to maintain the focus on poverty. It is important to note, however, that irrigation for farming by people not in poverty (Irrigation: Commercial) is not included here.

Unallocated water*:* This is water that is not assigned or needed for any use within the catchment. It can be drawn upon to meet new demands without negatively impacting any other use within the catchment. However, this amount may include water committed to downstream uses, including downstream environmental needs.

Environmental needs*:* Water needed to ensure a sustainable and healthy environment within the catchment. This quantity can be variable depending on the environmental conditions a country or area wishes to achieve, including rehabilitation efforts. It is important to note that this classification does not include downstream uses, which are included in the unallocated water quantity. Environmental needs are classified as a use in this paper as the focus of this paper is on the management of water. However, it is acknowledged that the environment also acts as a provider of water and has its own special management requirements.

In Figure 4, a flow diagram is shown to illustrate the concept when hydrologic aspects and water use patterns are more fully considered. Inflow into a basin represents inflow from surface and groundwater, precipitation, change in storage, and inter-basin transfers. Additionally, virtual water additions from food imports are counted as water inflows. Within the basin, water is used to meet anyone of several uses. These uses may, or may not, be applied to meeting social goals. Water used is either consumed or removed from the basin, such as through evapotranspiration. Where water is not used it flows downstream. The ability to recycle water is also addressed. Each process of use within a single basin example is termed a 'cycle.' Only two cycles are illustrated here, but this can be expanded to incorporate more or fewer cycles. Finally, water flows out of the basin. Water flowing out is both the physical water and the virtual water related to food exports.

To calculate the amount of water actually allocated to each use, the total amounts for each given use are summed over all cycles. This amount is compared to the target quantity, where the target level is the water allocation required to meet a social goal. The comparison is used to evaluate how well social goals are being met. However, not all uses will deplete water resources, so the sums of use amounts are not subtracted from the inflow. The total amount of water consumed, or depleted, is subtracted from the inflow to calculate outflow.

Two issues are briefly addressed here: water quality and use efficiency. Water quality is a growing and important issue in water resources management. Degraded quality of water can reduce the amount of water that is available for a specific use, such as drinking water. Efficiency of use also determines how much water is available for other uses. These are both important issues, but they are not addressed in the current paper. These will be addressed in a forthcoming paper.

Indicators for Water-Poverty Accounting

Using the WPAF, water allocations required to meet different poverty dimensions can be analyzed for each specific use. This allows water managers and policy makers to evaluate how well social goals are being met. These can then be compared to the actual situation to determine options for reallocating water to meet social goals. A set of indicators, based on current and target allocations, is developed to show the efficiency of water use to meet different demands. The indicators show were surplus water is available for reallocation, and where additional water is required to meet social and other types of goals. These indicators include:

? **Adequacy ratios** - that indicate how well either current or future needs are being met; and,

? **Bias indicators** - that show the bias of allocations of water either toward or away from meeting certain social goals.

Water-Poverty Accounting indicators are constructed using previously defined quantities including existing allocations, current basic needs allocation targets, and forecast future needs allocation targets. The indicators are discussed in detail below and summarized in Table 1. The first set of indicators concern adequacy indicators.

Adequacy indicators compare existing allocations with allocations required to meet both current and future needs (i.e. specific target quantities). These indicators are designed to show how specific components of water use are met, including social goals. A generic example of a Current Water Adequacy (CWA) indicator for a current use *i* is:

$$CWA_i = \frac{QCA_i}{TQ_i} \qquad (1)$$

where, QCA = current quantity of water allocated to use *i;*
TQ = quantity of water needed to meet target level for use *i.*

If equal to 1, the current allocations are perfectly matched to current needs. If less than 1, the current allocations are inadequate requiring reallocations from another sector. If greater than 1 too much water is currently allocated for this use.

Other descriptive indicators can illustrate important components of the broader situation. A Target Sufficiency Ratio (TSR) indicates whether current inflows are sufficient to meet current target levels. If negative, then current inflows are insufficient to meet all targets. It is calculated as follows:

$$TSR = 1 - \frac{\sum_i TQ_i}{I} \qquad (2)$$

where: I = inflow.

However, as not all uses deplete water, the TSR indicator does not mean that all uses cannot be met with current inflows. An alternative indicator could weight the target quantities by their use efficiencies before summation.

An Allocation Adequacy Ratio (AAR) shows whether identified deficiencies in current human basic needs allocations can be met by reallocating water currently used for non-basic needs. This is calculated as:

$$AAR = \left(\frac{TNB - TAB}{TNN}\right) x100 \qquad (3)$$

where, TNB = sum of target quantities for all basic human needs uses;
TAB = total quantity of water currently allocated to all basic human needs uses;
TNN = sum of target quantities for all non-basic needs uses.

If this indicator is less than or equal to 100, then there is a sufficient quantity of water available for current non-basic needs uses to meet the existing water deficiency. The AAR gives the percentage of the non-poor water uses which equals the deficit in basic needs uses. The smaller the ratio the "easier" the reallocation of water should be. That is, a reallocation should present a minimal impact on current non-basic needs activities.

A General Adequacy Ratio (GAR) summarizes the information in these two ratios. The GAR is produced from the results of the TSR and the AAR:

$$GAR ? \frac{AAR}{TSR} \tag{4}$$

The closer the GAR is to zero, the easier it will be to meet all human needs demands by reallocating water from non-human needs uses. Where the GAR is negative it is not possible to meet all target levels simultaneously.

A Human Needs Bias indicator (HNB) can be used to identify biases in current water allocations for meeting different objectives. This indicator compares basic needs uses and non-basic needs uses, but does not include environmental uses in its calculation. The HNB indicator is calculated as follows:

$$HNB ? \frac{?\frac{TAB}{TNB}?}{?\frac{TAN}{TNN}?} \tag{5}$$

where, TAN = total quantity currently allocated to all non-basic needs uses.

If the Human Needs Bias is equal to 1, there is no bias in water allocations. If greater than 1, the water allocations are biased toward meeting human rights needs for water. If less than 1, water allocations are biased against meeting human rights needs for water. It should be noted that this index does not indicate adequacy of allocations to either use. If basic human needs are adequately met by current allocations, then the HNB could assume a bias against meeting basic human needs, as water is put to more productive uses.

A Human Needs Indicator (HNI) is used to account for how well human needs are met under current water allocations. This indicator is constructed from the previously calculated basic human needs adequacy indicators, which are sanitation, hygiene/drinking water, production for consumption, and irrigation for household income. It is based on meeting social goals, rather than the relative quantities of water used to meet a certain goal. It is calculated as follows:

$$HNI ? AHAR ? 1 \tag{6}$$

where, AHAR = Average of all human basic needs adequacy ratios.

The HNI equals zero if all human needs are met. The HNI will be negative where there is a deficiency in meeting human needs. The larger the value of the HNI, the more deficient the current allocations are at meeting different human needs.

The indicators constructed here have concentrated on human basic needs. It is easy to construct "green" indicators by shifting target and actual allocations for the environmental category from non-basic needs to basic needs in the calculation of the indicators.

Since these calculations can be made for any geographic division it is possible to compile a set of indicators for any area, country, or region. These can be integrated into a GIS database with indicators separated into a range of categories and assigned graduated color codes. In this manner, maps can be constructed that can demonstrate the current condition as related to any indicator.

Case Study for the Mae Klong River Basin in Thailand

This section will demonstrate the use of the WPAF in the Mae Klong River Basin in Thailand. This case study is primarily to demonstrate use of the WPAF and therefore makes several simplified assumptions. These do not, however, distract from illustrating the framework's potential usefulness. Assumptions are that the basin is considered as an isolated area without food exports and imports and without inter-basin transfers of water. It is further assumed that rice is the only crop grown. A nutritionally adequate diet is considered to be equal to 2,100 calories and is referred to as the 'target diet.' This figure was used by the World Bank in Vietnam (although for a much more nutritionally diverse diet) (World Bank, 1999). It was assumed that all people were engaged in agriculture as their sole employment. Water used by agriculture is estimated as water applied rather than measured as evapotranspiration. For all uses, it is assumed that when water is used it is unavailable for any other use and there are no return flows.

The Mae Klong River Basin is located in the western part of the Central Region of Thailand. It is characterized by large pockets of rural poverty, where the rural population is largely engaged in agriculture as their main livelihood. The river basin is also home to the Greater Mae Klong Irrigation Project, which is the one of the largest irrigation systems in Thailand. Within the Irrigation Project there is very little poverty, but there is a significant amount of water use compared to other areas of the basin. Most data for this case study is derived from research done in Thailand for a six-country study entitled *Regional Study on the Development of Effective Water Management Institutions* (Biltonen, 2002). For the study, the basin was sub-divided into seven catchments. These seven catchments are utilized here and listed below, with abbreviations in Table 2. Figure 5 shows a map of these catchments.

Calculation of water targets

Estimating specific quantities of water for different demands is not simple. Requirements for drinking water and water for growing nutritionally adequate food supplies vary considerably, depending on the local climate, the crop grown, and the physical make-up and activity of the individual. The WPAF relies more on quantities of water needed to meet minimum requirements rather than demand. It is assumed that the more convenient water delivery is, the greater the quantity of water used (demanded) will become.

A low-end estimate for water requirements is 25 liters per day per capita ($l^{-1}d^{-1}c^{-1}$) for rural settings in Asia as a realistic requirement (Fude, undated). Another example given for water supply systems in the Punjab of India describes a designed capacity of 40 $l^{-1}d^{-1}c^{-1}$ (World Bank Water Demand Research Team, 1993). Estimates by the UN to meet all domestic uses for an average domestic consumer are given as 100 $l^{-1}d^{-1}c^{-1}$ (Fude, undated). For crops, an estimate of the range of water needs runs between 500 and 2000 $l^{-1}d^{-1}c^{-1}$ (Droogers, 2002). These estimates must be better refined for specific locations to reflect the actual minimal requirements for water. An estimate of water requirements for rice grown in Asian tropics and subtropics ranged from 700 mm to 1,500 mm of water (Guerra, Bhuiyan *et al.*, 1998).

The first step is to calculate targets for meeting the social goals related to water. For ease, drinking water, sanitation and hygiene were combined under a single category called "Domestic Uses." For domestic uses, the UN recommendation for urban water users of 100 l^{1}d^{-1}c^{-1} was used, which calculates as 36.5 m^{3} per capita annually. With a basin population of 2.2 million people, the total amount of water for domestic uses equals approximately 80 million m^{3} annually.

The target quantity for water used to meet nutritional requirements was calculated as follows. Data on the productivity of water for growing rice plants in different locations was observed (Guerra, Bhuiyan *et al.*, 1998). A rounded average of reported data was adopted for use in this case study, which equaled 0.4 kg/m^{3} of water used. Uncooked white rice is reported to contain 361 calories per 100 grams (PechSiam, 2002). Using the target diet of 2,100 calories per day per person yields a total requirement of 212 kg per year per person. Dividing this quantity by the water productivity estimate yields a total water requirement of 530 m^{3} of water per person per year. This was then multiplied by the population in the basin to produce a total water requirement for **nutritional water** needs of 1.16 billion m^{3} per year.

The target quantity for water requirements to meet the poverty level was calculated as follows. The basin population was multiplied by 1 to represent the international poverty line of $1 per day (World Bank, 2000). This amount was divided by the price of rice to calculate the quantity of rice required in order for the aggregate market value to equal US$1 per day for the population for a year. This was then divided by the water productivity (0.4 kg/m^{3}) to produce the total quantity of water required for everyone to reach the poverty line or the **unadjusted irrigation for household income** (18.2 billion m^{3}). From this amount, the previously calculated water for production for nutrition was subtracted leaving a target of 17.1 billion m^{3} needed for **irrigation for household income**.

Finally, the target level for irrigation for non-poor farming needs was calculated. The total target level was calculated by multiplying the current cropped area by the crop water requirement per hectare. The crop water requirement was estimated to be 11,000 m^{3}/ha per year, which is the average of the range reported for rice in the Asian tropics and sub-tropics (Guerra, Bhuiyan *et al.*, 1998). This produced a total target quantity of 37 billion m^{3} for the entire basin. The quantity of water needed for **irrigation for commercial agriculture** was estimated from current crop requirements minus the **unadjusted irrigation for commercial agriculture**. This amount was estimated as 18.8 billion m^{3}.

There is a difference between water for production for nutrition and irrigation for poor farmers. The price of rice in Thailand is approximately 0.1 US$/kg. Therefore, to meet the international poverty line of US$ 1 per day, a person would have to sell 10 kg/day. Whereas, the daily nutritional target was set at 2,100 calories and dry rice contains about 360 calories per 0.1 kg, then 2,100/360 = 0.6 kg of rice per day as compared to the income amount of 10 kg per day. This is the reason for the discrepancy in water requirements.

The water requirement for the environment was set at an arbitrary 25 percent of total inflow. The non-poverty water use target was set at the current amount of 30 million m^{3} for the entire basin, but for the sub-basins was set at zero, as data for these amounts was unavailable. Estimates of all target quantities for water use are reported in Table 3.

Calculations of Actual Water Use

Estimating actual current water use presents a more difficult challenge. Actual water use for domestic uses was estimated using current World Bank statistics for Thailand which indicate that only 80 percent of Thailand's population has access to safe drinking water (World Bank, 2002). Therefore, the target level for **domestic use** was simply multiplied by 0.8 to arrive at an actual water use quantity.

The total agricultural water use was calculated as the product of the crop water requirement per hectare, the percentage of farms irrigated, and the hectares grown added to the product of the per hectare rainfall average and the unirrigated crop acreage. The quantity of water used for the nutritional water requirement was then subtracted from the total agricultural water use to give non-subsistence irrigation amounts.

Based on current cropping patterns, nutritional requirements could easily be met and thus the actual water use for **production for nutrition** water is set equal to the target level. However, to make the case study result more illustrative 30 percent of water needed for nutritional needs in the Khwae Yai Upper (KHY) Sub-Basin was shifted to use by non-poor farmers for marketed crops. The actual quantity of water used for **irrigation for household income** was calculated in a similar manner. Since, the target level was below the amount based on current cropping patterns, the actual amount was assumed to equal the target level.

The quantity of water used for **irrigation for commercial agriculture** was calculated as the residual of total agricultural water less nutritional water use and irrigation for poor farming water use. The exception being the Khae Yai Upper sub-basin which was adjusted as previous explained. Non-poverty water use was set equal to the target level. Finally, actual water for environment was considered as any left over from the inflow after all other uses were accounted for.

Indicators

This section describes the calculation of the indicators that are presented in Table 3. The indicators show that for Domestic Uses current water allocations are inadequate, which all measure 0.8. Nutritional water allocations are adequate for all sub-basins except for the KHY Sub-Basin that was explicitly manipulated for this purpose. The KHY Sub-Basin has a **Nutritional Water Adequacy Ratio** of 0.7. Allocations for **Irrigation for Household Income** are generally adequate, except for the KHY and KHN_U Sub-Basins. These deficiencies are caused by the low inflows relative to the target levels for irrigation. Allocations for **Irrigation for Commercial Agriculture** are inadequate for all basins. This corresponds with the general coverage of irrigation systems in the basins. Of special significance is the KHN_U Sub-Basin where no water is allocated to Irrigation: Commercial. This is a result of all inflow being used by the previous basic needs uses. This indicates the likely case of high rural poverty. The rural poverty rate is reported as 46 percent, with 82 percent of the rural poor working in agriculture within the KHN_U Sub-Basin (Biltonen, 2002). For the basin as a whole, current environmental targets are being met. For the LPT and Greater Mae Klong Irrigation Project Sub-Basins, environmental needs are not being met as all water is used by other uses.

The **Target Sufficiency Ratio** shows that for the overall basin, current targets exceed current inflows. This is most likely due to the simplistic calculations used for water use where use efficiencies are not incorporated. Deficiencies are also reported for three sub-basins. The **Allocation Adequacy Ratio** shows that only the KHY Sub-Basin could not meet all basic needs by reallocating water from current non-basic needs uses. This is because of the relatively large deficits for meeting target levels, primarily Irrigation: Income. The **General Adequacy Ratio** shows that for the whole basin, 'basic needs' could be met by reallocating water from 'non-basic needs' uses; however, negative numbers indicate that target levels for both basic and non-basic needs cannot be met simultaneously. The **Human Needs Bias** shows that throughout the basin water is allocated in favor of meeting human needs relative to meeting non-basic needs. There is a very strong bias in the KHN_U Sub-Basin; however, this is due largely to the fact that non-basic needs are not being met at all. The **Human Needs Indicator** shows that for all basins basic needs are not being adequately met. The deficiency in meeting human needs is most severe in the KHY Sub-Basin, which is reported as -0.3. Results show that even though the Sub-Basins of KHY and KHN_U have strong biases in allocating water to human needs, human needs in the two sub-basins are not fully met.

The Water-Poverty Accounting framework shows that for the whole river basin, human needs are not being adequately met by the current water allocations. The deficiency in meeting human needs is most severe in the KHY and KHN_U Sub-Basins. Furthermore, the aggregate target level is too high for the water inflows to the basin and target levels should be reduced. This can be achieved by different methods including: promoting diversification of income sources, so that people rely less on irrigated agriculture; diversifying crops so that water demand is reduced; and, increasing the efficiency of water use. Increasing water use efficiency relates not only to agriculture but also domestic and industrial uses (although industrial water use has not been taken into account in this study). The WPAF clearly shows that water freed by increased efficiency within the Irrigation for Commercial Agriculture sector may be reallocated to human needs uses. If there are no efficiency gains within the basic needs sectors, then water must come from the non-basic needs sectors. For the two severely deficient Sub-basins (KHY and KHN_U), the WPAF results indicate that water reallocation would most likely come from the surplus allocated to the environment. The Adequacy Indicators for KHY and KHN_U show that irrigation uses are deficient. This would indicate that the development of upland irrigation might be a useful option to explore, although any detrimental effects must be considered, such as loss of habitat due to deforestation, soil fertility and erosion, which all may cause other future problems.

As a final note, the Mae Klong River Basin is considered one of Thailand's healthier river basins with relatively clean and abundant water supplies. The figures presented in this paper are to demonstrate the WPAF and should not be considered as definitive statements about the Mae Klong River Basin.

Conclusion and Discussion

The Water-Poverty Accounting Framework developed in this paper provides a framework to assess the current status of existing water allocations to meet poverty alleviation needs. The methodology provides a set of indicators to demonstrate the current adequacy of water allocations and implications for reallocations. Additionally, the methodology lends itself to fairly easy incorporation into thematic maps. In the future, it would be highly desirable to use data that is collected in a more disaggregated manner to gain a clearer picture. Additionally, more realistic hydrologic patterns will need to be incorporated. Future research and policy making will benefit through the use of a regional comparative approach that will allow for the results to be linked to different institutional conditions.

The Water-Poverty Accounting framework developed in this paper addresses the many dimensions of poverty. It also explicitly acknowledges the increased desire of decision makers to allocate resources to meet various social goals. The results of this accounting approach indicate where water reallocations are needed if social goals are to be met. This approach is seen as complementary to water accounting. In this way, water managers and researchers can observe both the physical and social dimensions of water conditions and allocations.

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James Dalton is a water resources management consultant with ITAD~Water based in the UK. He is currently working as a part-time assistant to the DFID Water Resources Adviser in the Water Sector Knowledge and Research program. He is completing his PhD thesis on irrigation water use and management in the Aral Sea basin, investigating the water management practices related to the contribution of groundwater to crop water requirements and the impact of high water tables on crop productivity, supported by Mott MacDonald. He has previous work experience in Zambia with the Commonwealth Development Corporation and in Israel where he worked for two and a half years with modern irrigation systems and managed two multi-national irrigation field teams.

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Figure 1. Conceptual framework of water as used for basic human needs and other uses in a fully allocated basin without access to other water sources.

Figure 2. Water-Poverty Accounting Framework

Figure 3. Different components of irrigation water's impact on poverty as included in the Water-Poverty Accounting Framework

Figure 4. Flow diagram of single basin, multiple cycle uses to meet social goals

Table 1. Summary and definition of WPAF Indicators

Table 2. Code abbreviations for study areas in the Mae Klong River Basin

Figure 5. Map of Mae Klong River Basin and Seven Study Catchments

Table 3. Results of the Water-Poverty Accounting Framework for the Mae Klong River Basin in Thailand

Table 1.

Indicator and Component Names	Abbreviation	Calculation	Boundaries	Interpretation
Current Water Adequacy	CWA_i	QCA/TQ	CWA=1 CWA<1 CWA>1	Current allocations perfectly matched to current needs. Current allocation inadequate and require reallocations. Current allocations excessive for current need.
Current Quantity Allocated	CQA_i			
Target Quantities	TQ_i			
Target Sufficiency Ratio	TSR	1-[? (TQ_i)/I]	TSR>=1 TSR<1	Current inflows are sufficient for current needs. Current inflows are insufficient for current needs.
Inflows	I			
Allocation Adequacy Ratio	AAR	[(TNB-TAB)/(TNN)]*100	<=100 >100	Sufficient quantity available for current non-basic needs to meet basic needs deficit. Insufficient quantity available from current non-basic needs to meet basic needs deficit.
Total quantity required to meet current human basic needs	TNB			
Total quantity currently allocated to meet human basic needs	TAB			
Total quantity required to meet current non-basic needs	TNN			
General Adequacy Ratio	GAR	AAR/TSR	0	Closer to zero the easier to meet all basic human needs by reallocating from non-basic needs allocations. If negative, cannot meet all targets simultaneously.
Human Needs Bias Indicator	HBN	[(TAB/TNB)/(TAN/TNN)]	=1 <1 >1	No bias in allocations. Biased against meeting human basic needs. Biased toward meeting human basic needs.
Quantity currently allocated to non-basic needs	TAN			
Human Needs Indicator	HNI	AHAR-1	=>0 <0	All human basic needs are met. Deficiency in meeting basic human needs.
Average of all human needs adequacy ratios	AHAR			

Table 2.

Area Names	**Code**
Khwae Yai Upper	KHY
Lam Taphoen	LTP
Khwae Noi Upper	KHN_U
Khwae Noi Middle	KHN_M
Lam Pachi	LPC
Mae Klong Plain Upper	MK_PU
Greater Mae Klong Irrigation Project	GMKIP

Table 3.

Targets	Basin	KHY	LTP	KHN_U	KHN_M	LPC	MK_PU	GMKIP
Current (million m^3)								
Target Total Ag Water	36,985	866	4,722	551	1,372	2,300	8,094	19,081
Target Domestic Uses	80	2.9	4.8	1.4	1.6	2.4	14	52.8
Target Nutritional Water	1,167	42	69	21	24	35	209	767
Target Irrigation: Income	17,096	613	1,012	303	349	519	3,068	11,233
Target Irrigation: Commercial	18,722	211	3,641	227	1,000	1,746	4,816	7,082
Target Non-poverty needs	30	0	0	0	0	0	0	0
Target Environmental Water	9,788	3,068	538	2,158	2,265	645	3,830	2,518
Actual (million m^3)								
Actual Total Ag Water	28,916	395	2,182	255	650	1,101	4,444	18,079
Actual Domestic Uses	64.3	2.3	3.8	1.1	1.3	1.9	11.5	42.2
Actual Nutritional Water	1,167	29	69	21	24	35	209	767
Actual Irrigation: Income	17,096	365	1,012	234	349	519	3,068	11,233
Actual Irrigation: Commercial	10,653	13	1,101	0	278	547	1,166	6,080
Actual Non-poverty needs	30	0	0	0	0	0	0	0
Actual Environmental Water	10,140	11,861	0	8,374	8,408	1,477	10,865	0
Indicators								
Basic Needs								
Domestic Uses	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Nutritional Water	1.00	0.70	1.00	1.00	1.00	1.00	1.00	1.00
Irrigation: Income	1.00	0.60	1.00	0.77	1.00	1.00	1.00	1.00
Non Basic Needs								
Irrigation: Commercial	0.57	0.06	0.30	0.00	0.28	0.31	0.24	0.86
Non-poverty Needs	1.00	-	-	-	-	-	-	-
Environmental Water	1.04	3.87	0.00	3.88	3.71	2.29	2.84	0.00
Target Sufficiency Ratio	-0.20	0.68	-1.45	0.69	0.60	-0.14	0.22	-1.15
Allocation Adequacy Ratio	0.08	2.20	0.09	0.83	0.00	0.02	0.02	0.17
General Adequacy Ratio	-0.39	3.23	-0.06	1.21	0.01	-0.17	0.11	-0.15
Human Needs Bias	1.75	10.14	3.30	>1,000	3.60	3.19	4.13	1.16
Human Needs Indicator	-0.07	-0.30	-0.07	-0.14	-0.07	-0.07	-0.07	-0.07

*Note: These figures are for demonstration purposes only and should not be taken to represent the situation in the Mae Klong River Basin

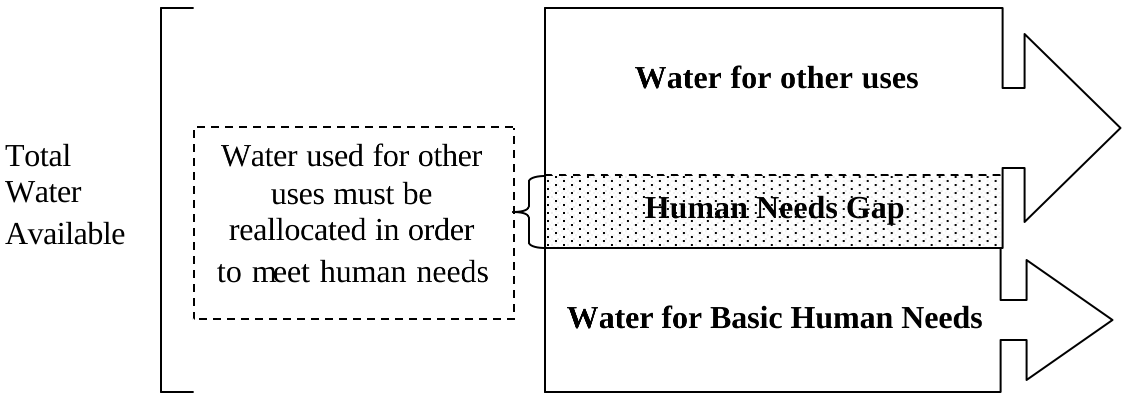

Total
Water
Available
Water used for other uses must be reallocated in order to meet human needs
Water for other uses
Human Needs Gap
Water for Basic Human Needs

Figure 1.

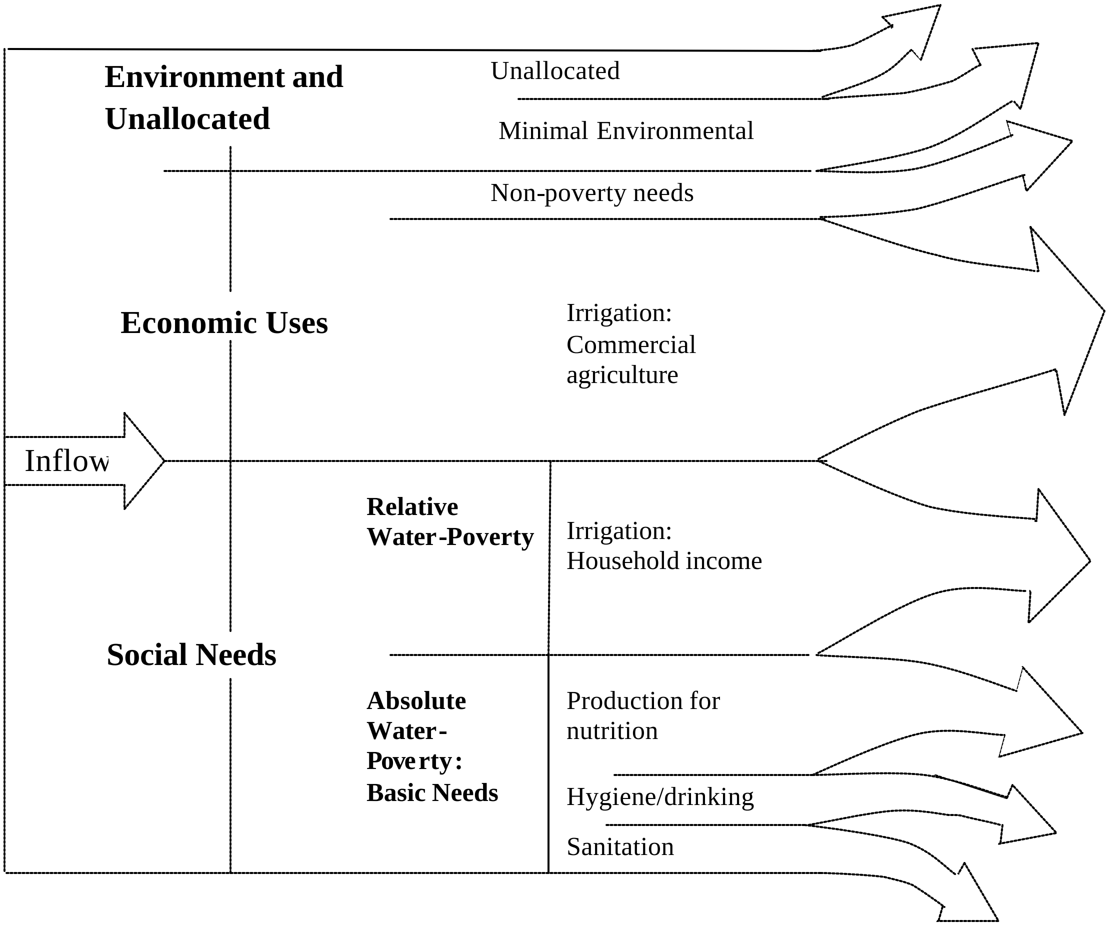

Environment and Unallocated
Unallocated
Minimal Environmental
Non-poverty needs
Economic Uses
Irrigation: Commercial agriculture
Inflow
Relative Water-Poverty
Irrigation: Household income
Social Needs
Absolute Water-Poverty: Basic Needs
Production for nutrition
Hygiene/drinking
Sanitation

Figure 2.

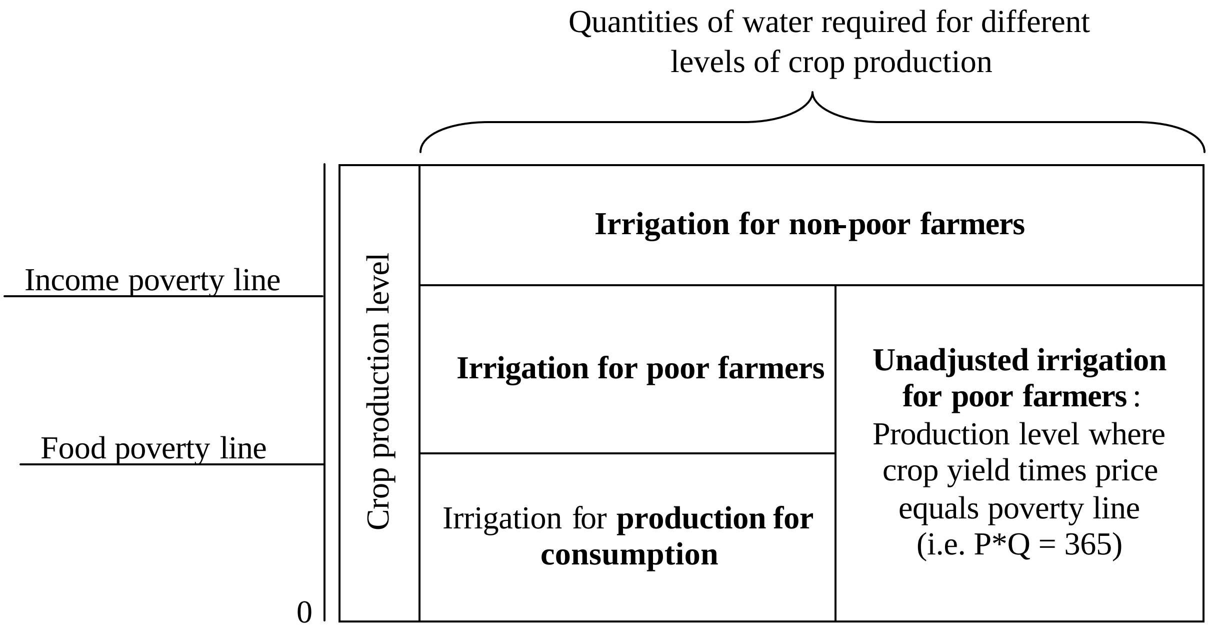
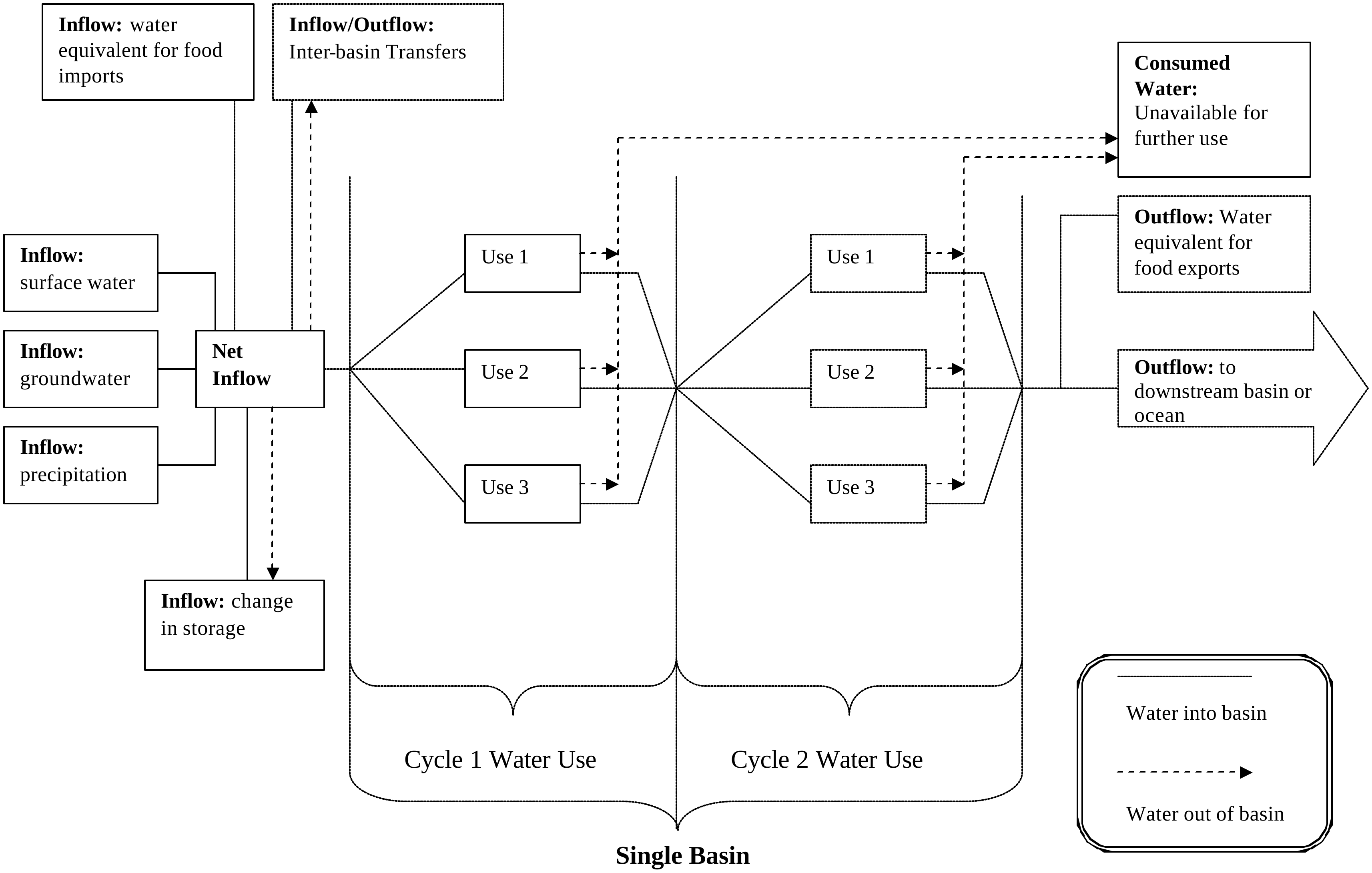

Quantities of water required for different levels of crop production
Irrigation for non-poor farmers
Income poverty line
Irrigation for poor farmers
Unadjusted irrigation for poor farmers: Production level where crop yield times price equals poverty line (i.e. P*Q = 365)
Food poverty line
Crop production level
Irrigation for production for consumption
0

Figure 3.



Inflow: water equivalent for food imports
Inflow/Outflow: Inter-basin Transfers
Consumed Water: Unavailable for further use
Outflow: Water equivalent for food exports
Inflow: surface water
Inflow: groundwater
Inflow: precipitation
Net Inflow
Inflow: change in storage
Use 1
Use 2
Use 3
Use 1
Use 2
Use 3
Outflow: to downstream basin or ocean
Cycle 1 Water Use
Cycle 2 Water Use
Single Basin
Water into basin
Water out of basin

Figure 4.

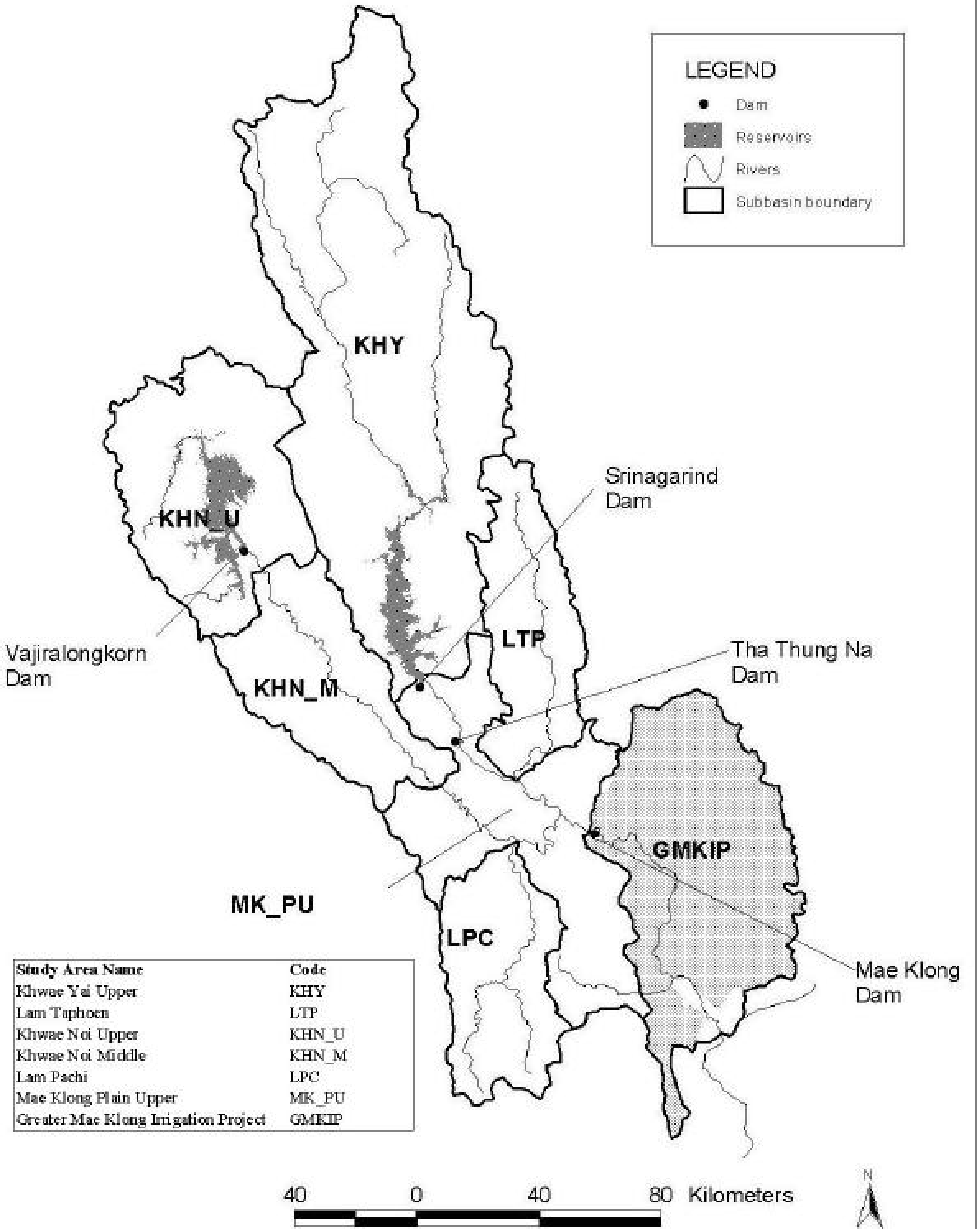


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Figure 5.