Chapter 4

Results and Discussion

4.1 Chiang Mai – Lamphun valley

4.1.1 The system boundary

The boundary of Chiang Mai–Lamphun valley as generated from the elevation map layer is confined to the area with the elevation of lower than 350 meters above mean sea level. Its extent is 446000 m. to 526000 m. E and 1966000 m. to 2123000 m. N in Indian 1975 datum and UTM projection Zone 47 (Figure 4). The study area covered about 300,000 hectare of the cultivated flood plain in the south west of Chiang Mai province and the north east of Lamphun province. The average altitude was about 300 meter above mean sea level. This valley also covered four large Royal Irrigation Department (RID) projects namely, Mae Taeng, Mae Feag-Mae Ngad, and Mae Kuang in Chiang Mai and Mae Ping Kao in Lamphun.

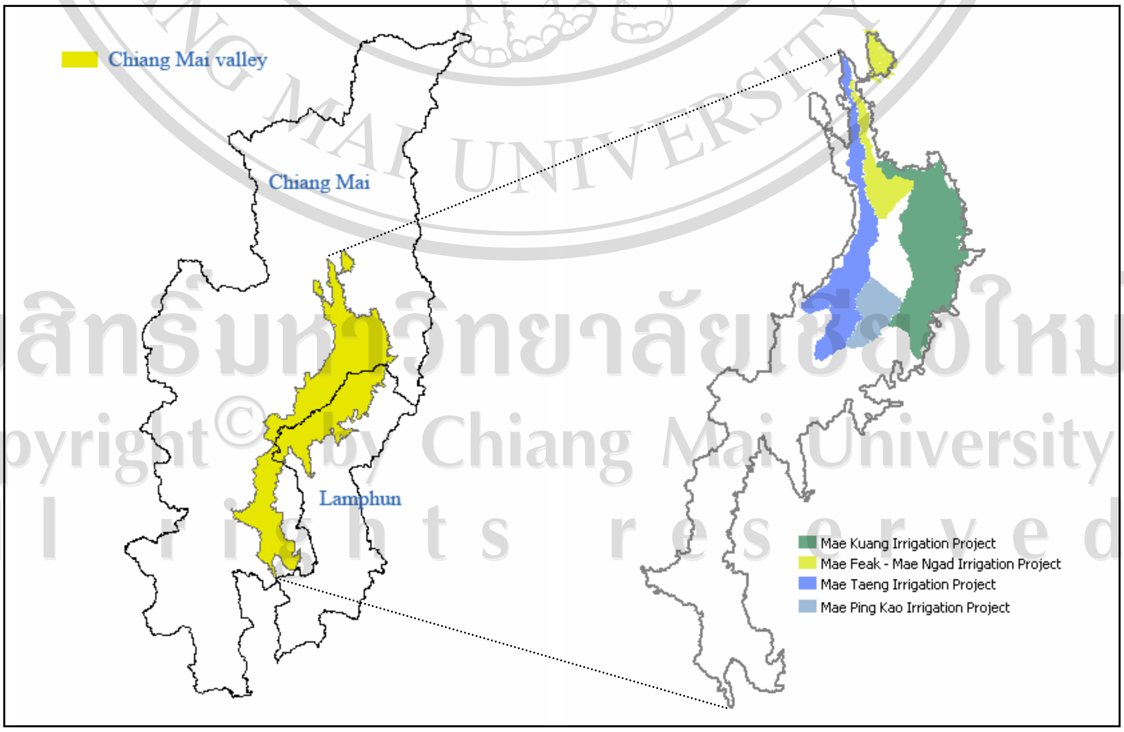


Figure 4 Chiang Mai – Lamphun valley and large irrigation project areas

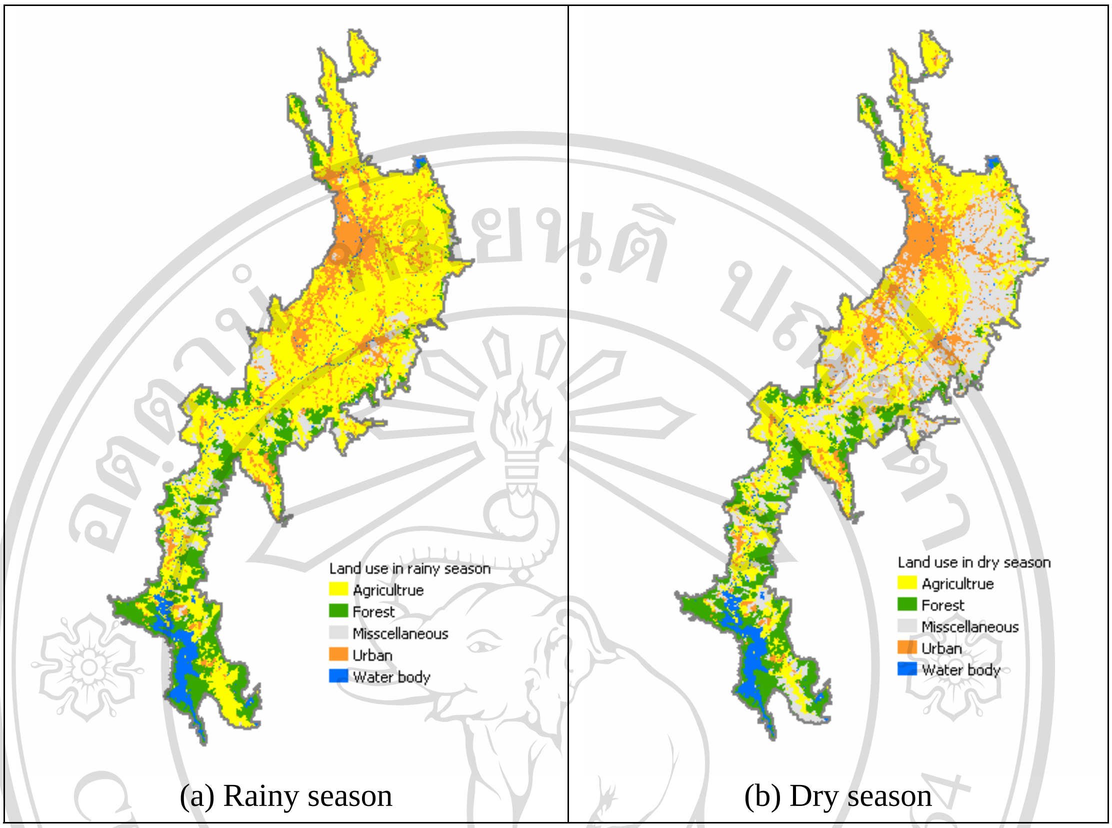
4.1.2 Land use

The intensive cropping systems of Chiang Mai - Lamphun valley was possible because of the upper part of the valley received irrigation water supply from four large royal irrigation projects (Figure 4). In 2000, about 60 percent of Chiang Mai valley was cultivated in rainy season (Table 2; Figure 5). The paddy rice was the main crop occupying about 90,000 hectare (about 50 percent of the cultivated area). Orchard (Longan and Mango) was the second common crops covering about 80,000 hectares.

Only half of the agricultural areas in rainy season were used for the subsequent dry season cropping (about 30 percent of total areas) because more than half of irrigation structure was weir that cannot store water for irrigation throughout in dry season. However, most of orchard was irrigated by pumping water from the Ping river and the tube wells.

Table 2 Land use distribution by types and seasons in Chiang Mai-Lamphun valley

Land use	Rainy season		Dry season	
	Area (ha)	Area (%)	Area (ha)	Area (%)
Agriculture	175,435	58	110,311	36
Paddy rice	93,109	31	6,540	3
Field crops	7,241	2	26,856	9
Vegetables	4	0	881	0
Orchards	77,826	26	77,826	26
Urban	44,012	14	44,012	14
Water resources	13,247	4	13,247	4
Forests	45,573	15	45,573	15
Miscellaneous	26,368	9	91,261	30
Total	304,635	100	304,635	100



(a) Rainy season (b) Dry season

Figure 5 Land use of Chiang Mai – Lamphun valley (Sangchyoswat *et al.*, 2005)

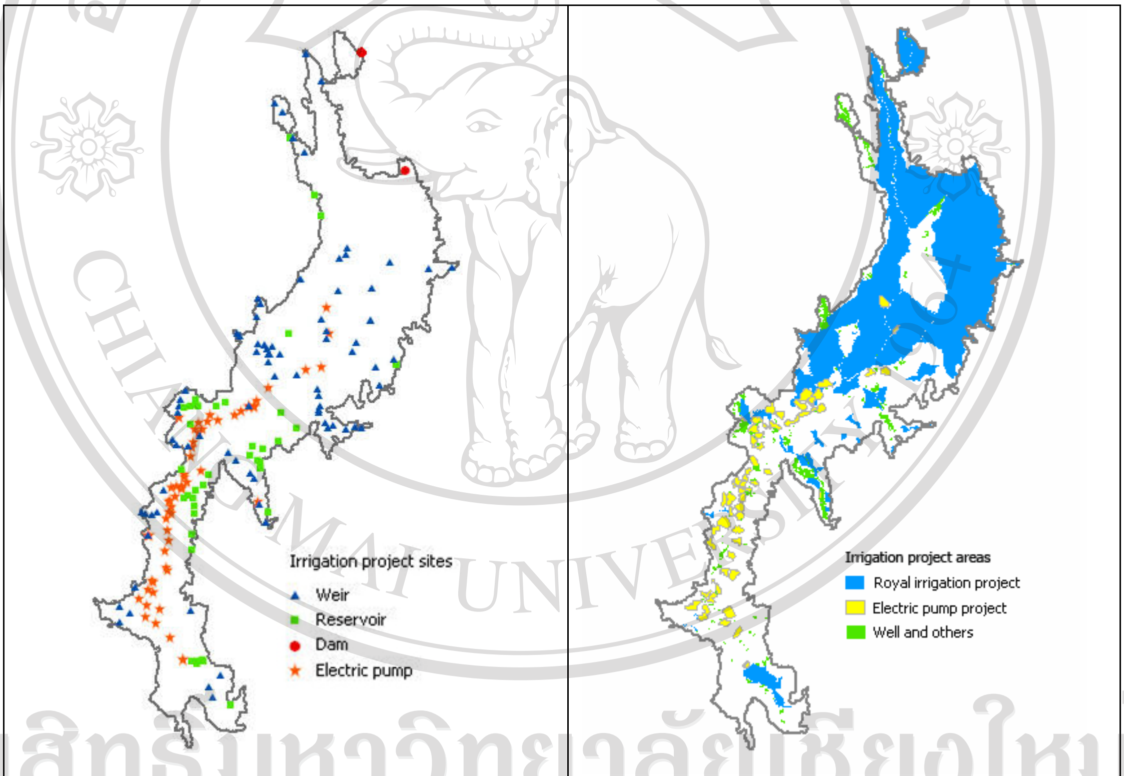
4.1.3 Irrigated areas

The irrigated areas from large irrigation projects were about 90,000 hectares (Table 3) or about half of total irrigated areas while those of medium irrigation projects in Chiang Mai – Lamphun valley were about 20,000 hectares or only 10 percent. Most of RID projects are small, there were 111 small projects scattering throughout the valley and supply irrigation water to 30,000 hectare of cultivated land.

There exist also the electric pump stations that supply water to 58 service areas near the Ping river covering about 14,000 hectare of arable land. These wells can serve only about 9,000 hectare of the second crops, they are also main source of water for people consumption outside the service areas of municipal water supply.

Table 3 Types of irrigation projects and irrigated areas in Chiang Mai – Lamphun valley

Irrigation types	Site (no)	Site (%)	Area (ha)	Area (%)
Royal irrigation projects	123	2.65	148,983	86
Large irrigation projects	3	0.06	95,022	55
Medium irrigation projects	9	0.19	22,041	13
Small irrigation projects	111	2.40	31,920	19
Electric pump projects	58	1.25	14,172	8
Well and others	4,329	93.44	9,190	5
Total	4,633	100.00	172,345	100



(a) Irrigation project sites (b) Irrigated areas

Figure 6 Irrigation systems in Chiang Mai – Lamphun valley

4.1.4 Climatic zones

There were three distinct climatic zones in rainy season. The climatic zone 1 covers the large area of the central part of the Chiang Mai valley, while the upper and the lower part of the valley are influenced by climatic zone 2 and zone 3 respectively. For dry season, two main climatic zones were distinguished (zone 1 and 2). The climatic zone 1 in the rainy season is similar to the one in the dry season, characterized by similar distribution patterns of rainfall and temperature.

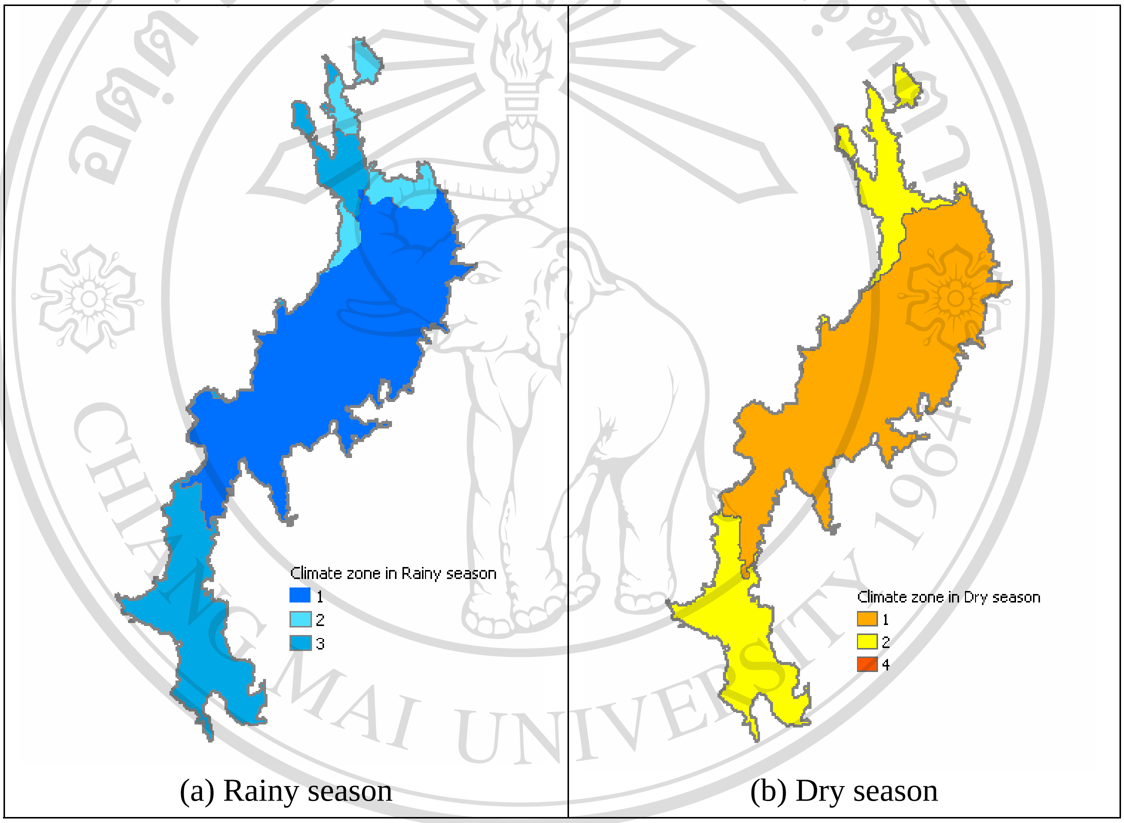


Figure 7 Climatic zones in Chiang Mai – Lamphun valley

4.2 Geodatabase development

4.2.1 UML class diagram of land mapping units

A personal geodatabase for water productivity tools was designed as shown in the UML diagram (Figure 8). The UML diagram displays data structure and relationship between LMUs class and other object classes. The LMUs class was the polygon feature data format that serves as the core class for analyzing data and displaying the resulting maps. There are four main table classes that relate with LMUs class through key fields, namely *tblClzWeekly*, *tblCrpCoeff*, *tblIrrSupply*, and *tblEconSuit*.

The *tblClzWeekly* class represents climatic data that describes weather data of each climate zone consisting of rainfall, maximum and minimum temperature, solar radiation, wind speed, elevation, and evapotranspiration in weekly time steps. The *tblCrpCoeff* class describes crop coefficients in each growing stage of each crop. The *tblIrrSupply* class describes irrigation water supply measured weekly at the head work of irrigation projects. The *tblEconSuit* class describes data that were received from economic land evaluation (Samranpong *et al*., 2005) such as cost of inputs, crop yield, price, and net return.

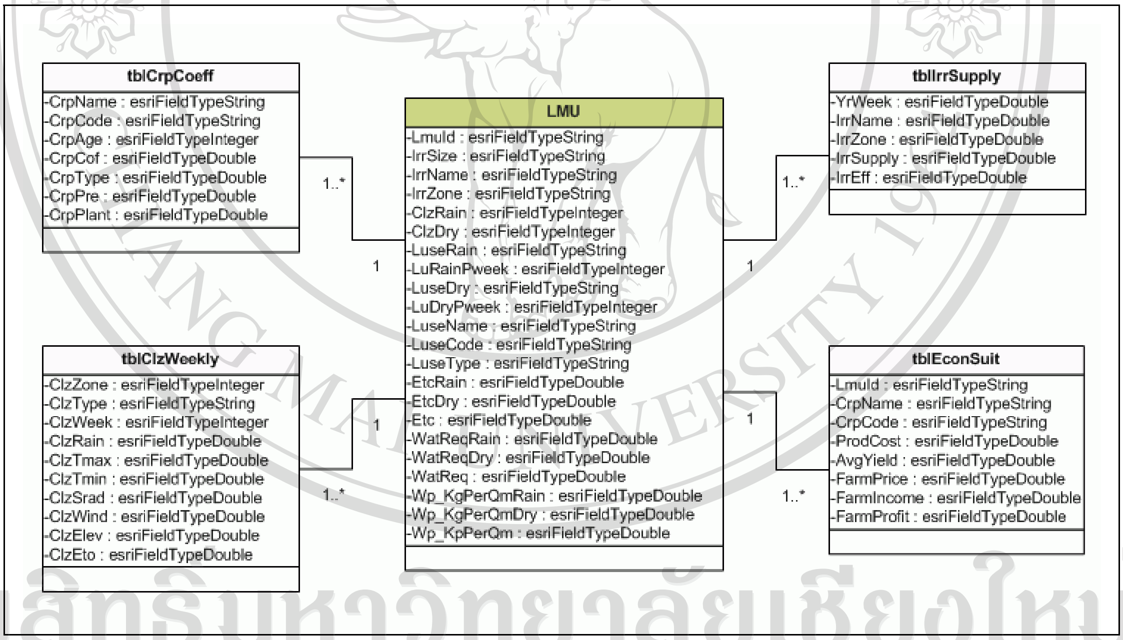


Figure 8 Structure of land mapping units in UML class diagram

4.2.2 UML class diagram of irrigation project data

The irrigation projects layer were also included in water productivity geodatabase for describing general description of each irrigation project. The irrigation geodatabase were categorized into three parent classes, *IrrigationPolygon*, *IrrigationLine*, and *IrrigationPoints*.

The *IrrigatedArea* child class was inherited from *IrrigationPolygon* parent class for describing the irrigation project boundary and irrigation zone. The *IrrigationCanal* child class was inherited from *IrrigationLine* parent class for describing canal name, order, and length. The *IrrigationProject* child class was inherited from *IrrigtionPoints* parent class for describing type, irrigated area, and water supply of irrigation project.

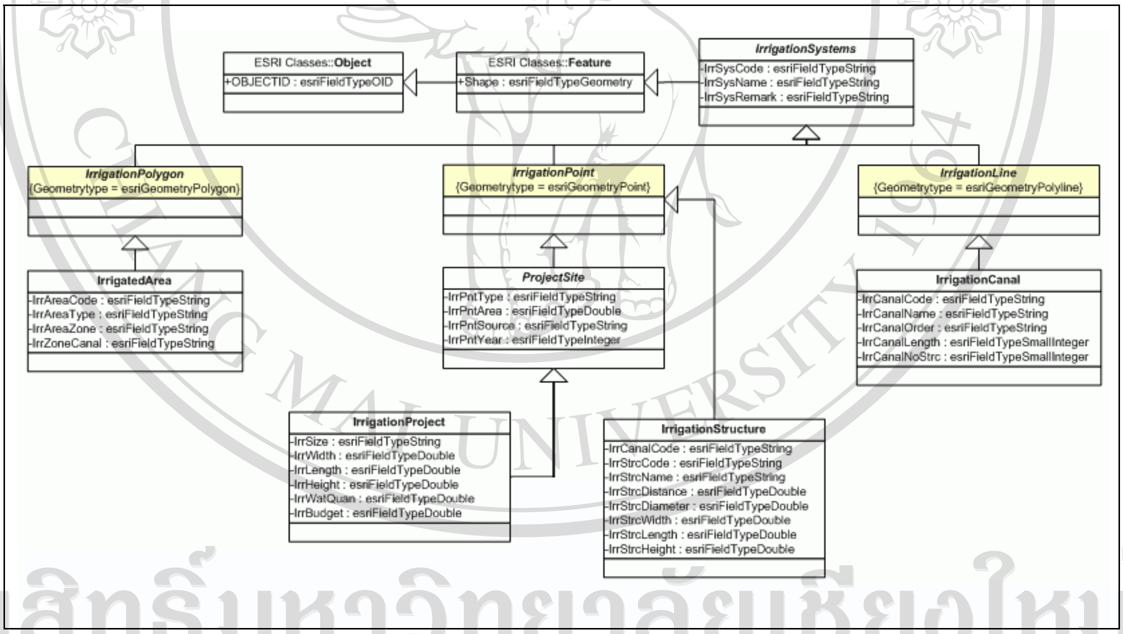


Figure 9 Structure of irrigation project in UML class diagram

4.2.3 Water productivity geodatabase

The UML diagram (Figure 8 and 9) created from Microsoft Visio 2002 were converted into .xml file and the geodatabase schema was built in ArcCatalog of ArcGIS system as shown in Figure 10. The available spatial data were imported into water productivity geodatabase according to the data structure described above. The metadata were also created for describing the GIS data in each feature class (Figure 11).

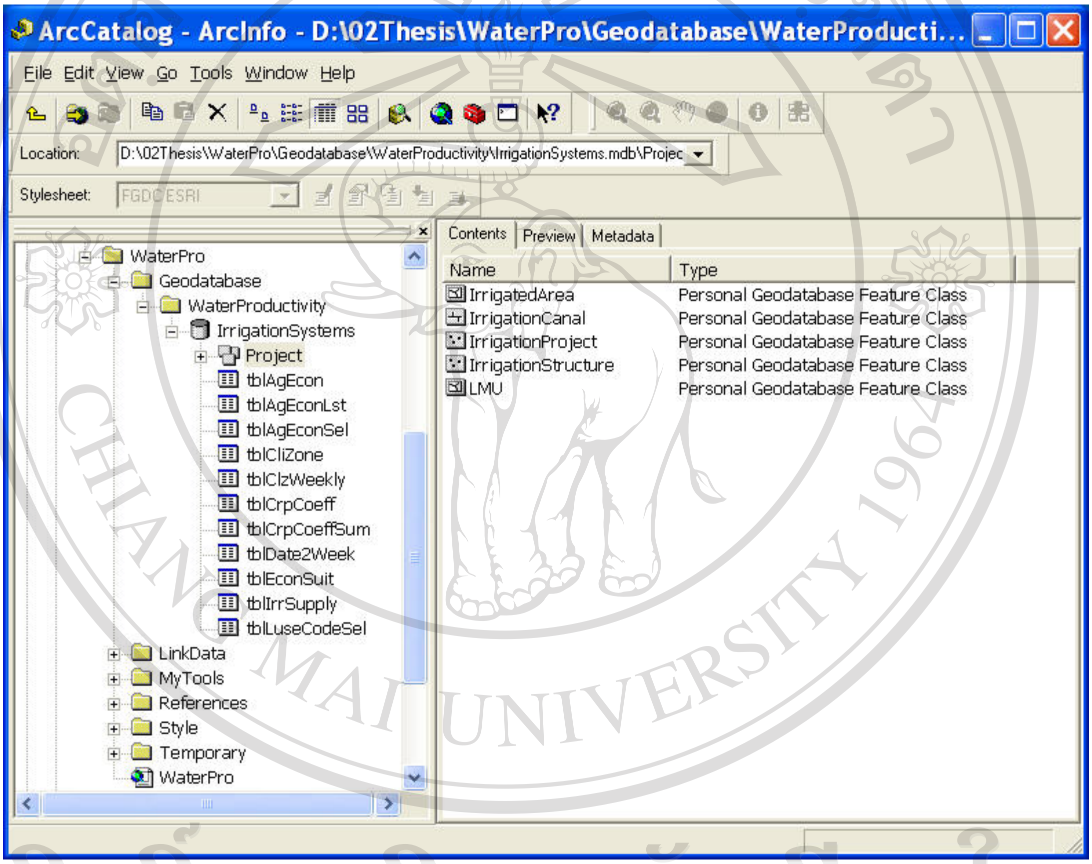


Figure 10 Water productivity geodatabase

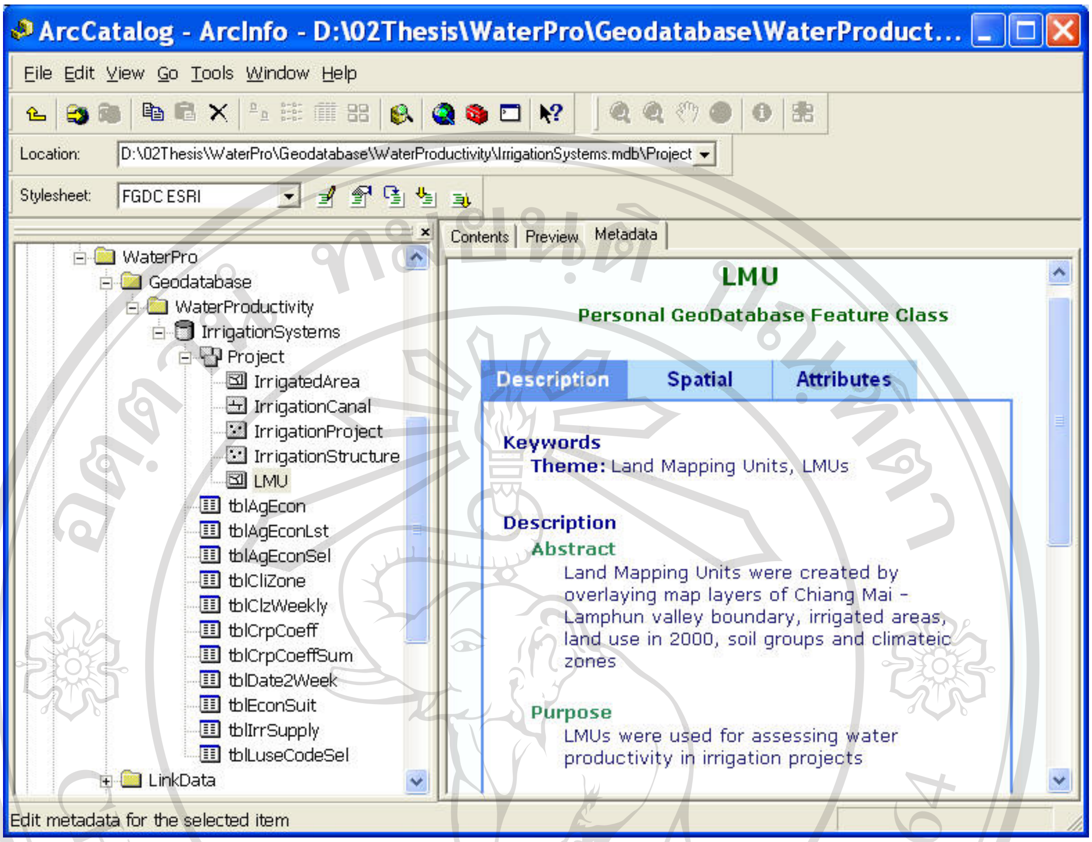


Figure 11 Metadata of water productivity geodatabase

4.3 Water productivity tools

4.3.1 Framework of water productivity tools

The Framework of water productivity assessment tools shows the interaction between the user and water productivity tools through graphic user interfaces (Figure 12). The graphic user interface was developed for the user to select the study area at two levels, the irrigation project and the irrigation zone levels. The analysis and simulation tools were designed for estimating crop water requirement and water productivity. The mapping windows were used for displaying results from analysis and simulation tools in forms of map, table, and graph.

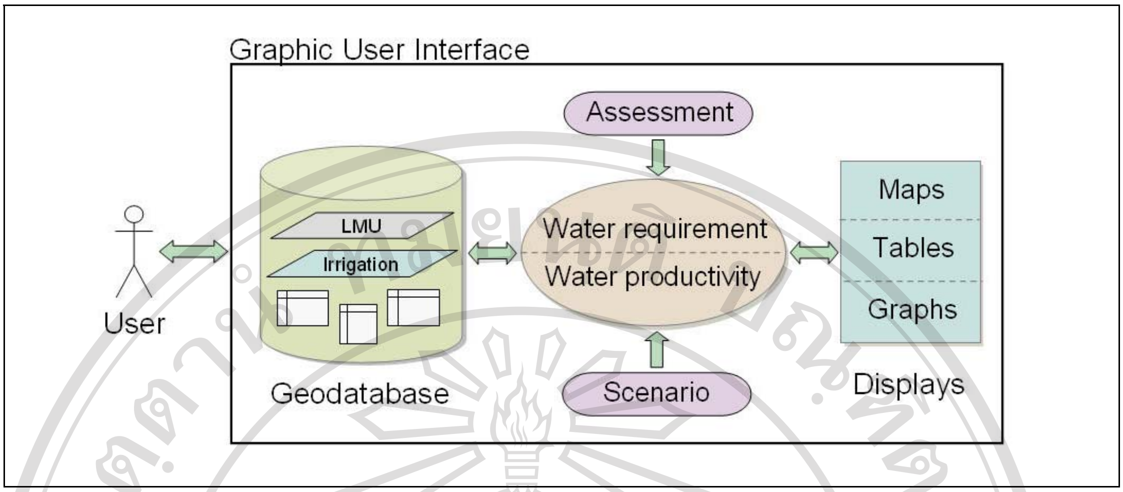


Figure 12 Framework of water productivity tools

4.3.2 Menu bar structure of water productivity tools

The menu bar of water productivity consists of four main menus, "*Selecting study area*", "*Display general data*", "*Water productivity*", and "*Scenario analysis*" (Figure 13). The "*Display general data*" comprises of three sub menus, "Structure and irrigation water supply", "Land uses", and "Climatic zones". The "*Water productivity*" menu contains two sub menus, "Water requirement", and "Water productivity". The "*Scenario analysis*" composes of three sub menus, "Changing all land use systems", "Changing some land use areas", and "Changing water supply, price and production cost".

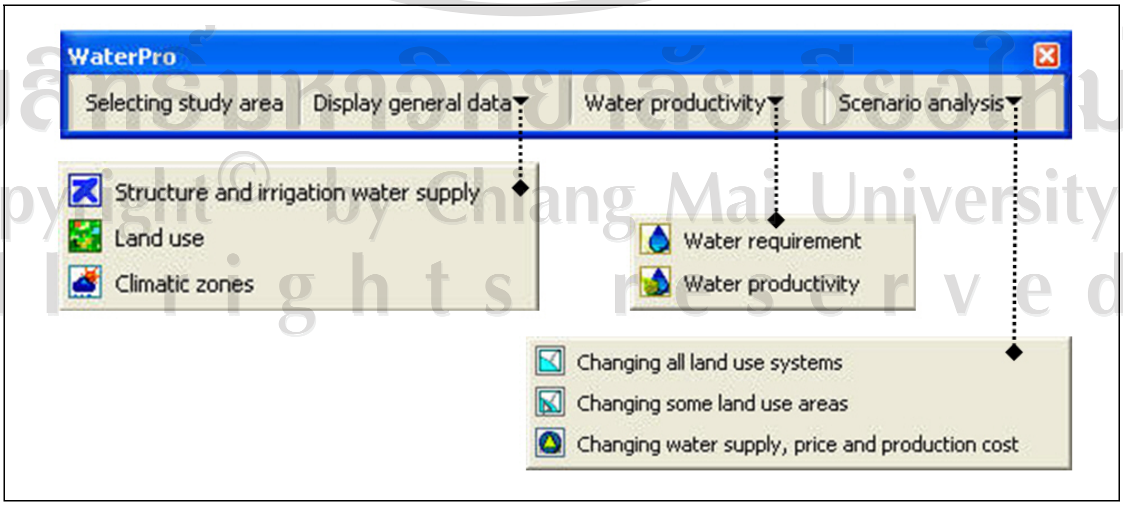


Figure 13 Menu bar structure of water productivity tools

4.3.3 User interfaces for water productivity tools

a. Selecting study area window

The selecting study area window (Figure 14) was the first user interface for setting the scope of study area. The drop down list was design as a guideline for user to select the boundary of irrigation project follow the hierarchy system that are irrigation project type, irrigation project size (large and medium project), irrigation name (Mae Taeng, Mae Feag-Mae Ngad, Mae Kuang, and Mae Ping Kao irrigation project), and drill down to irrigation zone.

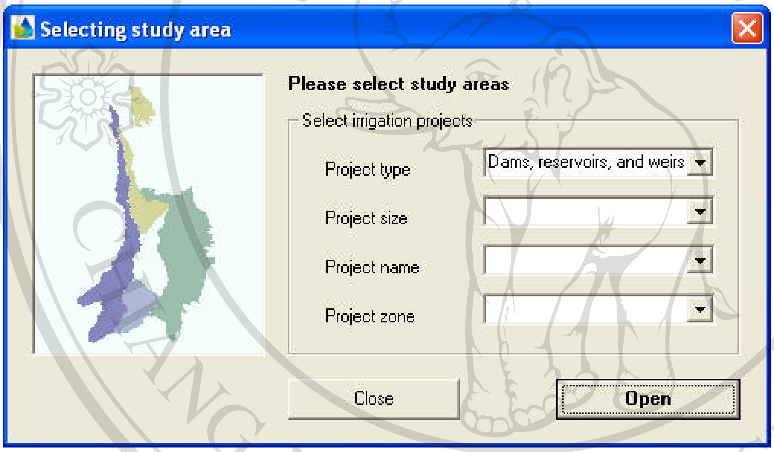


Figure 14 A window for selecting study area

b. Irrigation structure and water supply window

The irrigation structure and water supply window (Figure 15) was developed to display the general data of irrigation project. The map frame consists of the check boxes for displaying the components of irrigation data such as project site, project boundary, project zones, and project structures. The lower frame was designed for displaying the irrigation water supply from the head work of irrigation project between 2000-2004 and the five-year average.

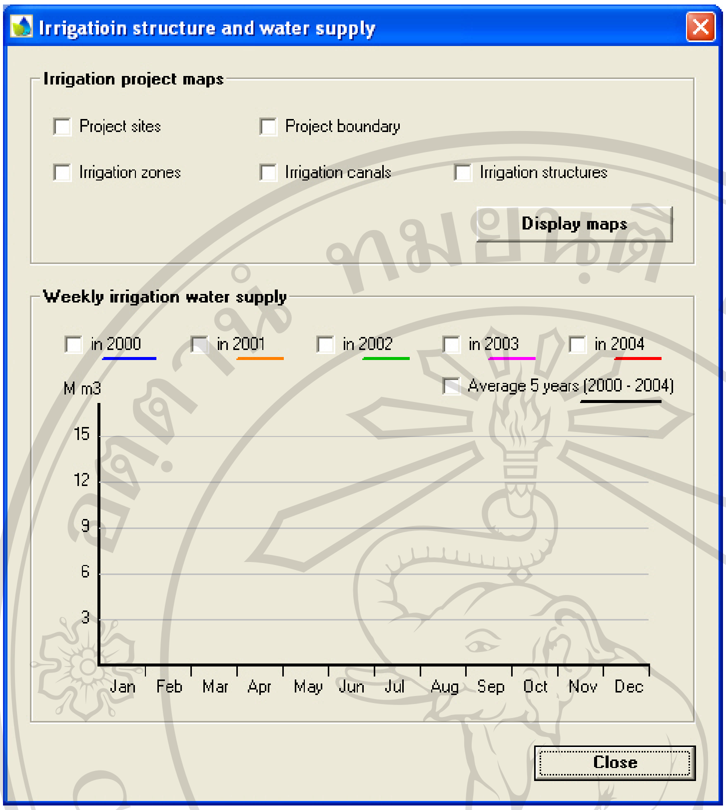


Figure 15 A window for selecting irrigation structure and displaying water supply

c. Land use window

The land use window (Figure 16) was developed to display the general data of land use in the study area. The map frame contains the check boxes for displaying the series of land use map such as land use map in the rainy season, land use map in the dry season, and land use maps on yearly basis. The frame in the middle is used for searching the specific land use from the query statement. The frame at the bottom of this window is used for displaying the crop calendar of cropping systems in the selected project.

d. Climatic zone window

The climatic zone window (Figure 17) was designed to display the description for each climatic zone in the irrigation project. This map frame includes the check boxes for selecting climatic zones in the rainy and dry seasons. The bottom of this frame is used for displaying rainfall, minimum and maximum temperature, solar radiation and evapotranspiration on weekly basis.

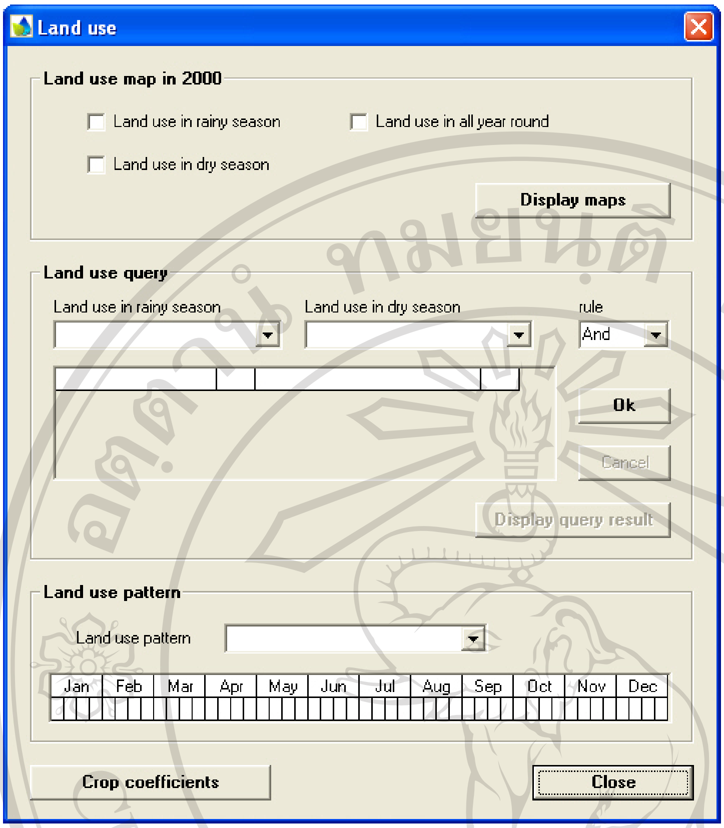


Figure 16 A window for dispaying land use types and crop calender

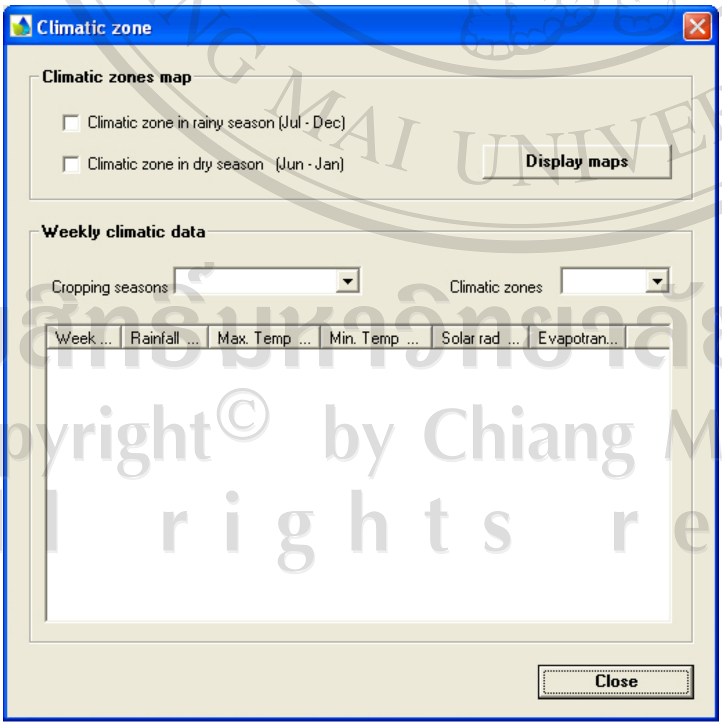


Figure 17 A window for displaying climatic zone and climatic data

e. Water requirement window

This window (Figure 18) is used for estimating water requirement by setting irrigation efficiency, water for land preparation (mm.), and water for household people consumption (liter/people/day) at the upper left corner (Figure 18).

The top right frame was used for setting the map display such as classification format (Natural breaks, Equal interval, Quantile) and number of classes. The bottom part of this window was used to display the summary data of water required by categorized by irrigation project, land use type, group of land use, and irrigation zone. Data can be summarized by season or yearly basis and expressed as water height (mm.) and water quantity (Mm^3).

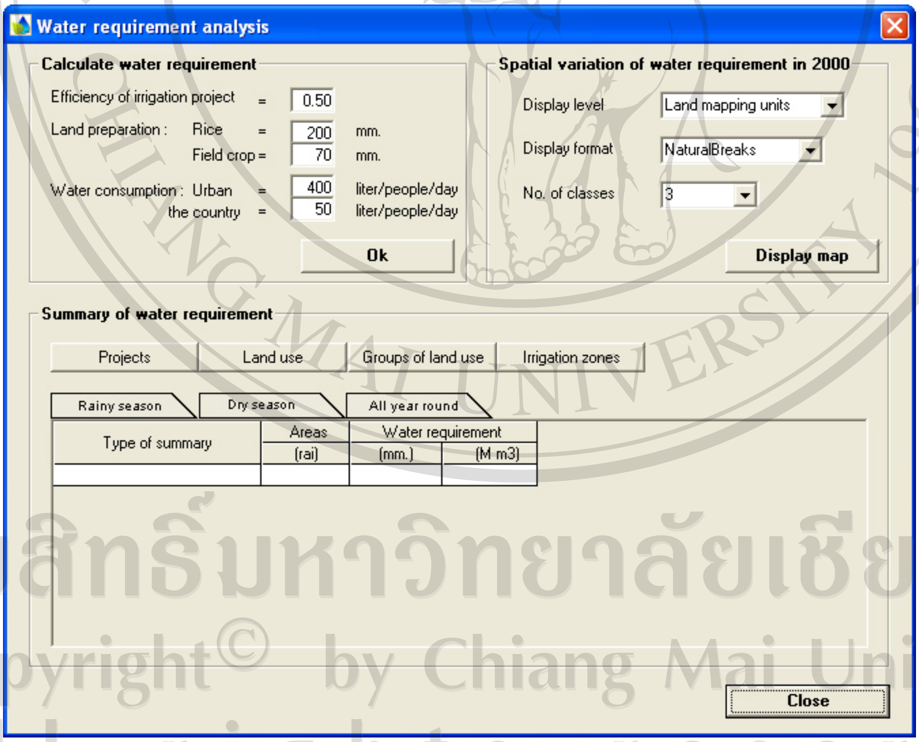


Figure 18 A window for displaying estimated water requirement

f. Water productivity window

The water productivity window (Figure 19) was the main analysis window to assess water productivity in irrigation project. The top left frame describes the summary of economic data for crops in the selected area, costs (baht/rai), crop yields (kg/rai) crop prices (baht) income (baht/rai) and net return (baht/rai) are displayed.

The top right frame was used for setting the map display such as classification format (Natural break, Equal interval, Quantile) and number of classes similar to that of the water requirement window. The bottom frame was used to display summarized water productivity and its component table such as agricultural areas, crop yield, net return, and water consumption, categorized by irrigation project, land use, and irrigation zone for each season and all year round.

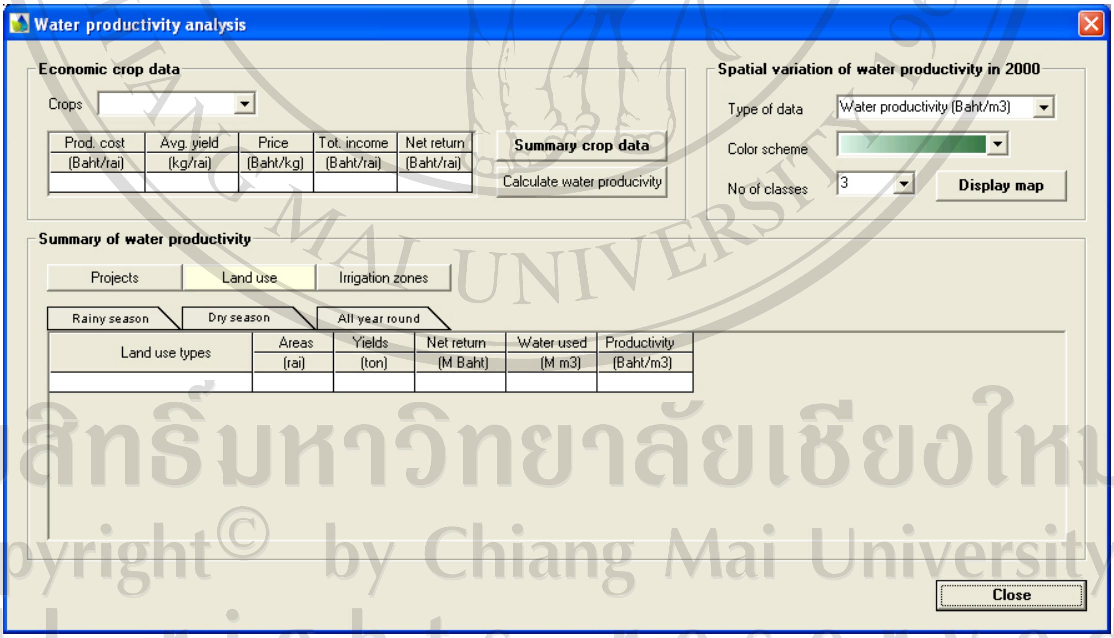


Figure 19 A window for displaying estimated water productivity

g. Changing all land use systems window

This window (Figure 20) allows the user to assess the effects of changing all land use systems on water productivity. The user can select the desired land use type to be changed and the replacing land use by setting crop type and planting date in rainy and dry season. After finished setting, the tool will calculate new crop water requirement and evaluate water productivity of the study area. The new result will be compared with the situation in 2000.

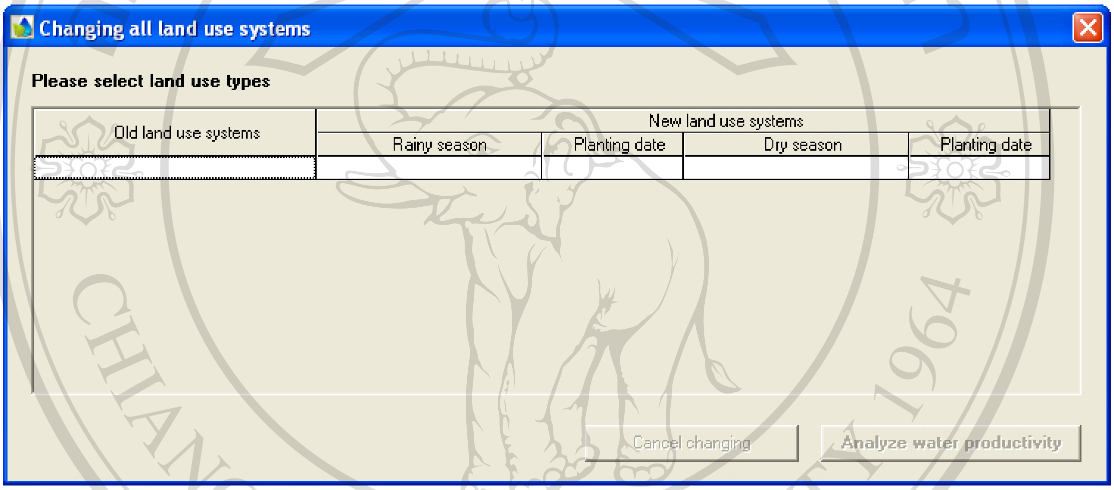


Figure 20 A window for changing all land use systems

h. Changing some land use areas window

The user may want to test the effects of changing some land use areas on water productivity from this window (Figure 21). The user can select or query the specific target areas and replace the existing and use type with other cropping system, set planting date for any cropping season. The program will then estimate crop water requirement and water productivity of the target areas, the new result will be compared with the situation in 2000.

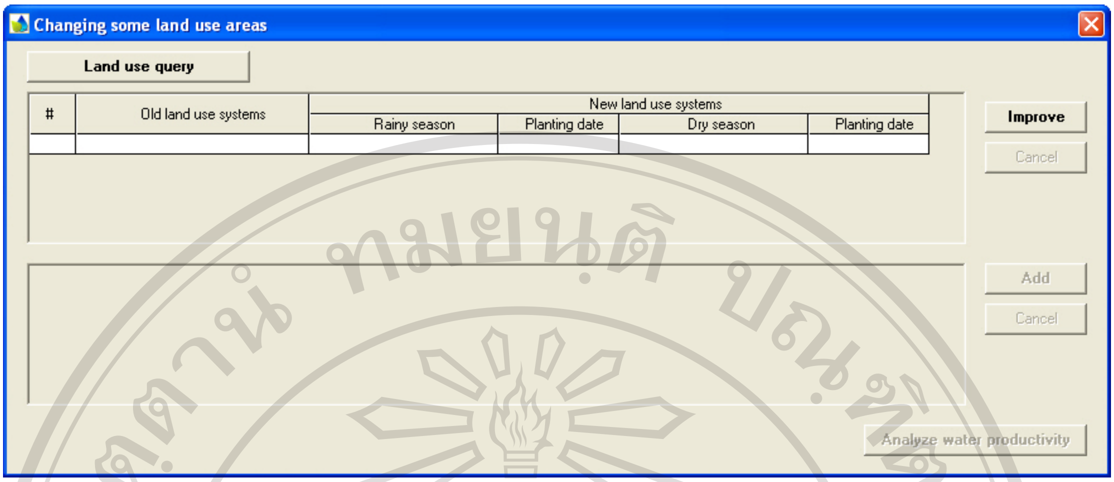


Figure 21 A window for changing some land use areas

i. Changing water supply, price, and cost window

The purpose of this window (Figure 22) is to evaluate the effects of different scenarios of changing water supply, cost of inputs and price of outputs on water requirement and water productivity. The top left frame is used for setting the quantity of water supply, the level of input cost, and output price in percentage compare with the situation in 2000. The lower left frame is used for displaying the value of input cost and output price of the changing situation. The frame on the right allows user to set the strategy for allocation the water supply in each irrigation zone such as weighted by crop water requirement, weighted by water productivity, and defined by user. The results of the estimation for crop water requirement and water productivity will be compared with the situation in 2000.

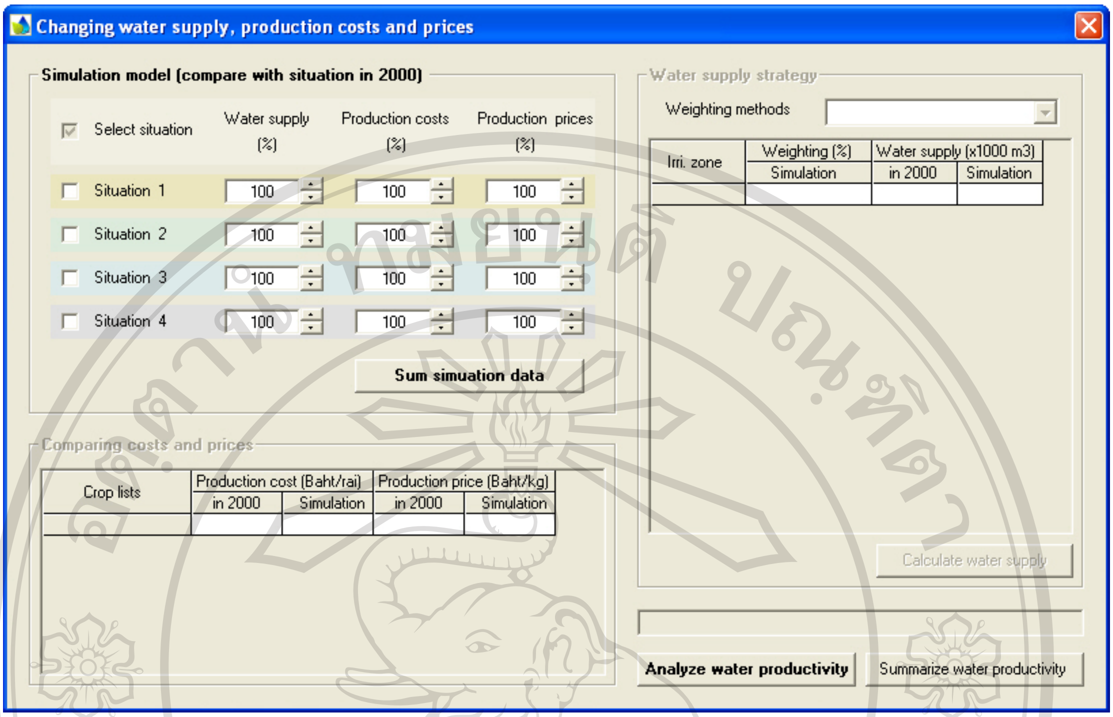


Figure 22 A window for scenarios analysis on changing amount of water supply, cost of inputs and output price

4.4 Water requirement assessment

4.4.1 Water requirement of Mae Taeng irrigation project

Mae Taeng irrigation project distributed water to about 32,000 ha of the irrigated areas. Figure 23 shows spatial variability of irrigation water requirement as the results of spatial analysis. The dark blue areas represent the cropping areas that consume highest amount of irrigation water expressed in mm. These areas were concentrated in the upper and lower parts of the irrigation project where double cropping systems were practiced. The middle zone of the project area required less water due to the conversion of land into urban areas were about 12,000 ha or 38 percent of irrigated areas. Water requirement for the whole project throughout the year was about 259 Mm^3, 116 Mm^3 in the rainy season and 143 Mm^3 in the dry season (Table 4).

In the rainy season, paddy rice and longan were two main cropping systems that consumed highest amount of irrigation water. An estimated of about 83 Mm^3 and 30 Mm^3 were required to sustain the production of paddy rice and longan respectively due to the extent of cultivated areas of both crops. For the dry season, longan cropping areas (about 4,200 ha) still consumed huge amount of irrigation water (about 64 Mm^3), followed by soybean areas (about 5,800 ha) and onion/garlic areas (about 2,200 ha) which required about 44 Mm^3 and 23 Mm^3 in the project area. When consider all year round consumption, it was found that longan consumed more quantity of water than rice+soybean, rice+onion/garlic and other cropping systems (Table 4).

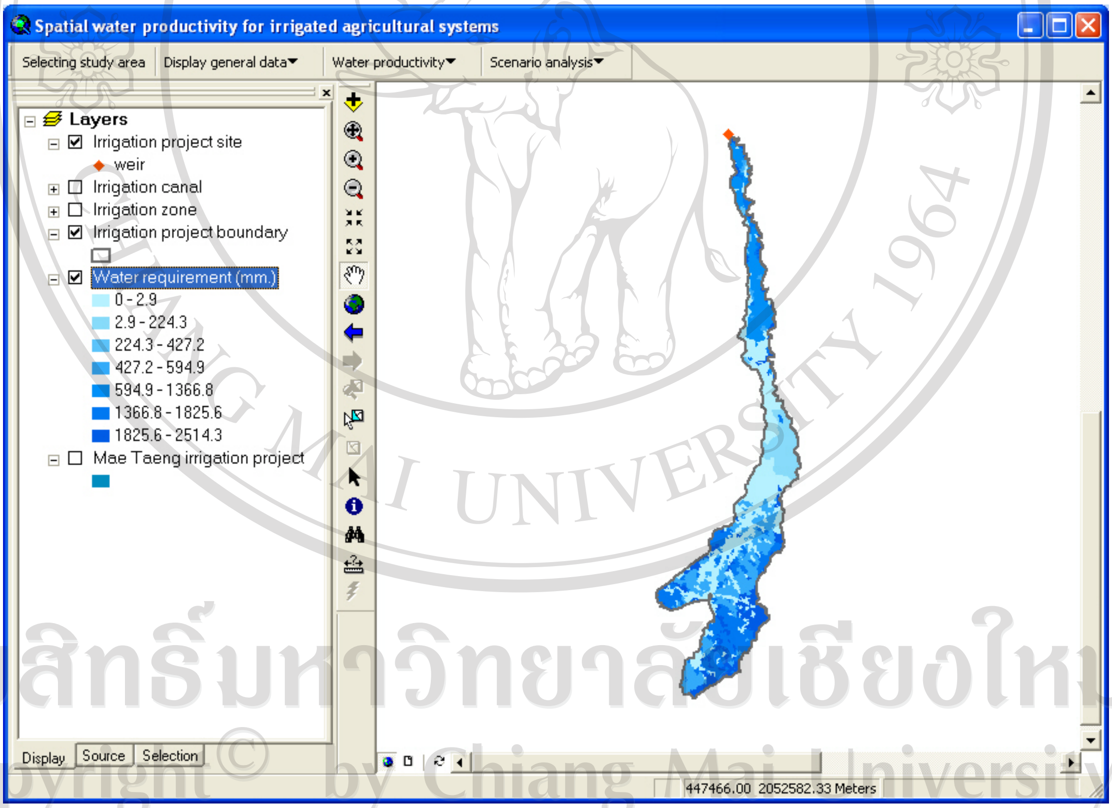


Figure 23 Spatial distribution of water requirement in Mae Taeng irrigation project

Table 4 Water requirement of different cropping systems in Mae Taeng irrigation project

Land use	Area (ha)	Water requirement (Mm^3)		
		Rainy season	Dry season	All year round
Rice	5,960	34.54	0.00	34.54
Rice+Rice	426	2.48	5.16	7.64
Rice+Soybean	5,851	32.64	43.74	76.38
Rice+Vegetable	55	0.28	0.47	0.75
Rice+Onion/Garlic	2,219	12.99	22.58	35.57
Longan	4,205	29.25	64.15	93.40
Mixed orchard	273	2.02	5.31	6.50
Other	12,856	1.96	1.51	4.31
Total	31,845	116.16	142.92	259.09

4.4.2 Water requirement of Mae Feag-Mae Ngad irrigation project

The Mae Feag - Mae Ngad irrigation project covered the irrigated areas of about 17,000 ha. The irrigation water requirement in each LMUs are shown in Figure 24. Almost of Mae Ngad irrigation project and the western part of Mae Feag irrigation project required high amount of water due to intensive cropping systems. The cropping areas in rainy season required 74 Mm^3 while 117 Mm^3 was needed in the dry season (Table 5). The total water requirement for the whole year was 191 Mm^3.

The paddy rice and longan/mango, main cropping systems required about 43 and 29 Mm^3 of irrigation water respectively in the rainy season. In the dry season, the second crop of paddy rice occupied about 2,400 ha and required about 32 Mm^3 of irrigation water to sustain their production. The longan and mango areas covered about 5,100 ha and required nearly double or about 51 Mm^3 of irrigation water comparing to that was consumed in the areas where the second crop of paddy rice were grown. For the all year round water requirement of the main cropping systems in the Mae Feag – Mae Ngad irrigation project, longan and mango, rice+rice, and rice+soybean consumed about 80, 48 and 22 Mm^3 of water respectively.

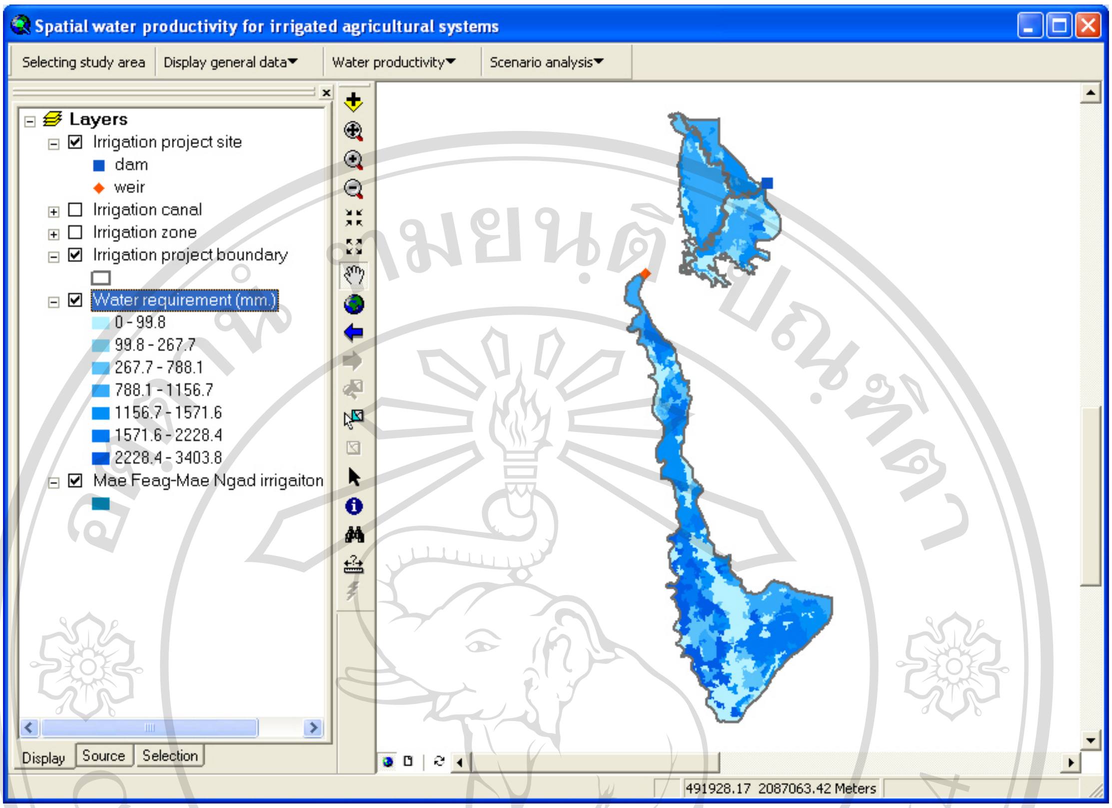


Figure 24. Spatial distribution of water requirement in Mae Feag-Mae Ngad irrigation project

Table 5 Water requirement of different cropping systems in Mae Feag-Mae Ngad irrigation projects

Land use	Area (ha)	Water requirement (Mm^3)		
		Rainy season	Dry season	All year round
Rice	1,678	10.66	0.00	10.66
Rice+Rice	2,418	16.47	31.82	48.29
Rice+Soybean	2,038	7.71	14.53	22.24
Rice+Vegetable	11	0.08	0.11	0.19
Rice+Potato	577	4.23	4.21	8.44
Rice+Onion/Garlic	1,212	3.86	9.86	13.72
Longan	2,740	15.18	37.71	52.89
Mango/Longan	2,403	13.81	13.81	27.62
Other	4,197	2.26	4.54	6.81
Total	17,275	74.26	116.59	190.86

4.4.3 Water requirement of Mae Kuang irrigation project

The Mae Kuang irrigation project service areas were about 48,000 ha (Figure 25). The cropping areas in the irrigation project require about 323 Mm^3 of water (Table 6). A single crop in the rainy season was mainly practiced at the time of this study because of the unfilled reservoir that was completely constructed in 1993 (Figure 5). In the rainy season, the cropping areas required about 215 Mm^3 of irrigation water while only half of irrigation water was needed (108 Mm^3) in the dry season.

Paddy rice was the main crop in the rainy season covering more than 80 percent of the project areas. These areas required about 165 Mm^3 of irrigation water. Relatively small areas of mango and longan required about 29 Mm^3 of water. However, in dry season only some areas of rice+rice, rice+soybean, rice+tobacco, rice+onion/garlic could receive irrigation water of less than 10 Mm^3 (Table 6).

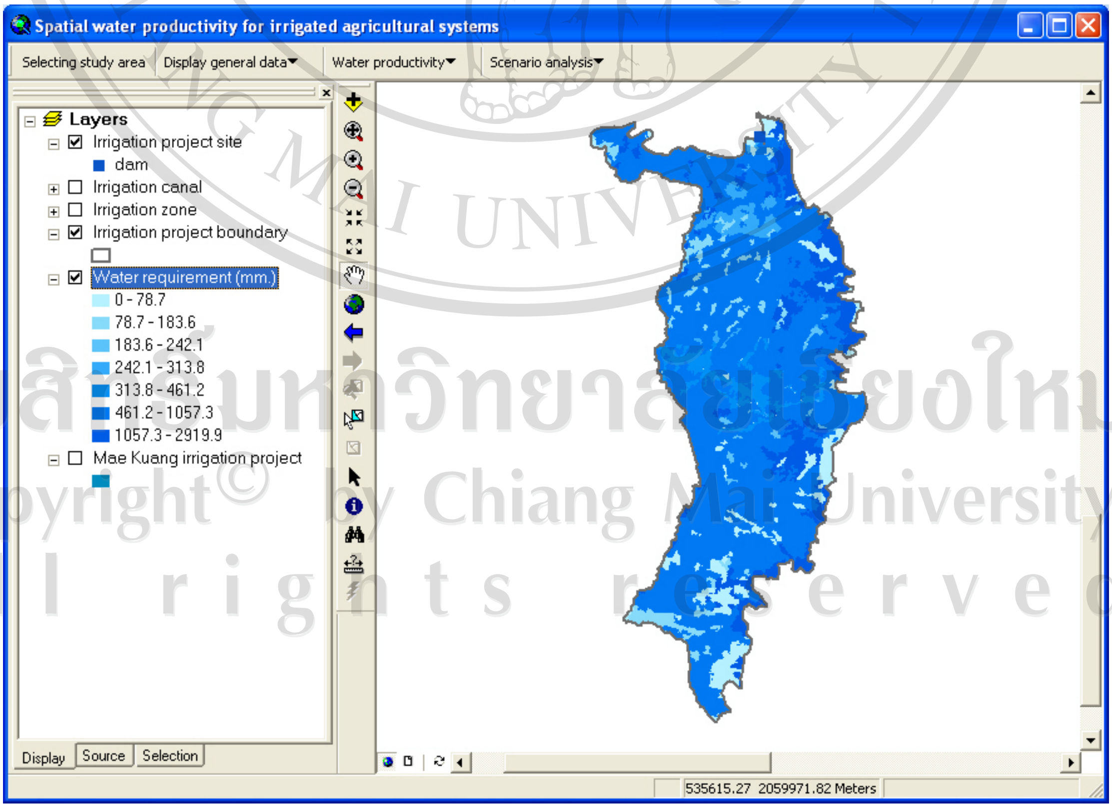


Figure 25 Spatial distribution of water requirement in Mae Kuang irrigation project

Table 6 Water requirement of different cropping systems in Mae Kuang irrigation project

Land use	Area (ha)	Water requirement (Mm^3)		
		Rainy season	Dry season	All year round
Rice	27,559	150.96	0.00	150.96
Rice+Rice	502	1.80	5.63	7.43
Rice+Soybean	412	1.20	3.16	4.36
Rice+Vegetable	68	0.38	0.56	0.94
Rice+Tobacco	1,264	7.07	9.78	16.85
Rice+Onion/Garlic	613	3.43	6.09	9.52
Longan	1,453	9.12	20.47	29.59
Mango/Longan	5,593	20.00	20.00	39.99
Other	10,115	21.44	41.95	63.43
Total	47,578	215.40	107.64	323.07

4.4.4 Water requirement of Mae Ping Kao irrigation project

The extent of irrigated areas in Mae Ping Kao irrigation project were about 11,000 ha. The spatial distribution of water requirement map in this area is shown in Figure 26. Most of irrigated areas required very high amount of irrigation water because the main areas were planted with longan. The entire cropping areas in the project required about 263 Mm^3 of water for the whole year (Table 7). The project should to supply about 96 Mm^3 of water in the rainy season and 167 Mm^3 in the dry season.

About 75 percent of the service areas were used for longan plantation, although paddy rice was still grown in small part of the areas. In the rainy season, longan and paddy rice required about 78 and 17 Mm^3 of irrigation water respectively. In the dry season, only 1,400 ha were used for the second paddy rice that required about 22 Mm^3 of irrigation water. The longan occupied about 7,200 ha of land and consumed about 145 Mm^3 of irrigation water.

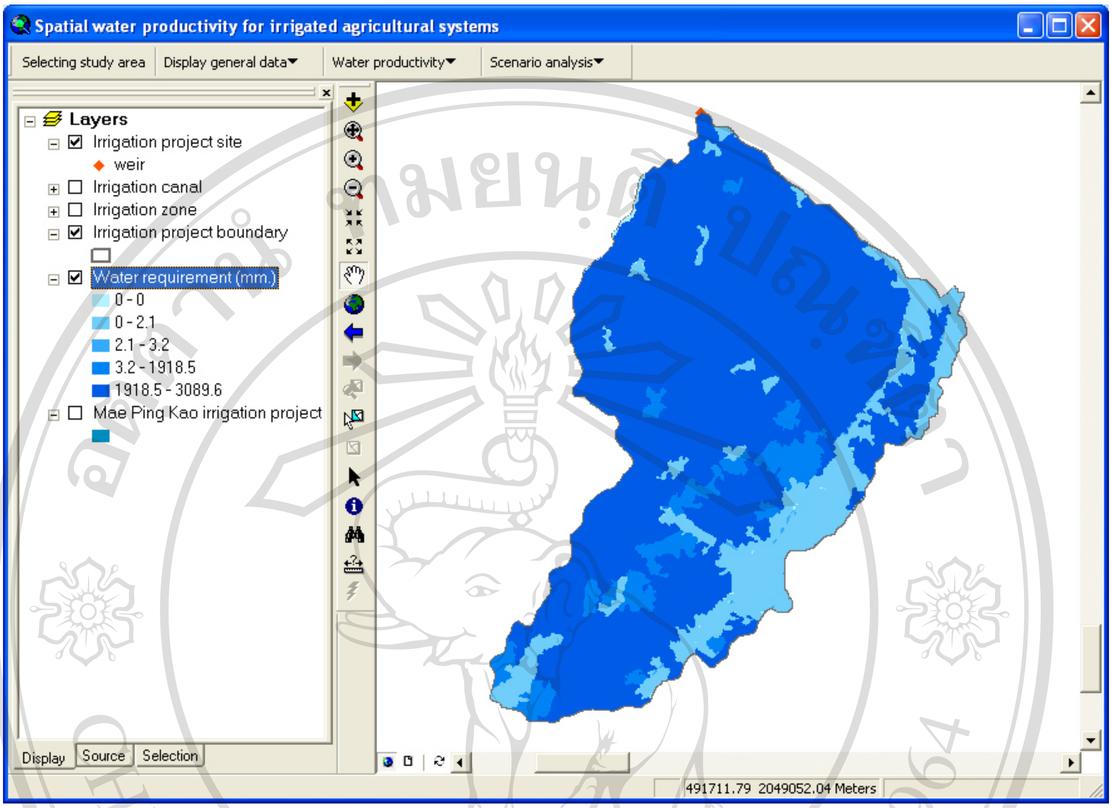


Figure 26 Spatial distribution of water requirement in Mae Ping Kao irrigation project

Table 7 Water requirement of different cropping systems in Mae Ping Kao irrigation project

Land use	Area (ha)	Water requirement (Mm^3)		
		Rainy season	Dry season	All year round
Rice	716	5.88	0.00	5.88
Rice+Rice	1,406	11.54	21.55	33.09
Rice+Soybean	38	0.31	0.40	0.71
Rice+Vegetable	12	0.10	0.13	0.23
Longan	7,225	78.23	144.99	223.22
Other	1,787	0.02	0.01	0.03
Total	11,184	96.08	167.08	263.16

4.4.5 Water requirement of all irrigation projects

Spatial variability of yearly irrigation water requirement expressed in mm. of water for all four irrigation projects (Figure 27) clearly show higher water requirement in the Mae Ping Kao and Mae Feag-Mae Ngad irrigation projects than in the other projects. Much less water per unit area was required in the central part of the Mae Taeng irrigation project comparing to the rest of Mae Taeng irrigation project and most of Mae Kuang irrigation project.

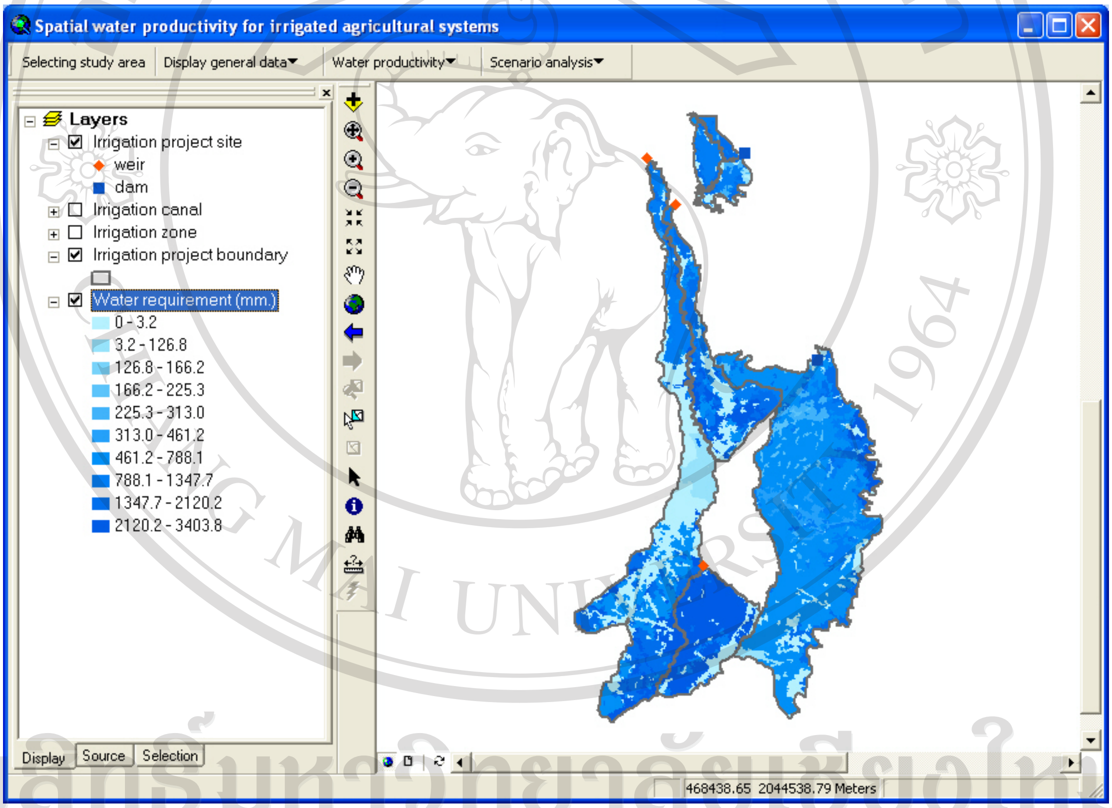
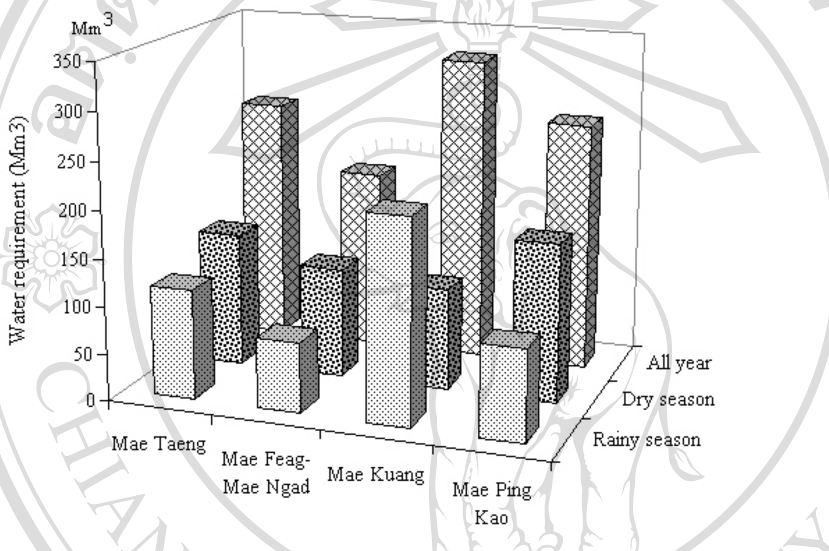


Figure 27 Spatial distribution of yearly water requirement (mm.) in all irrigation projects

Figure 28 also shows the quantity of water requirement in each season. In the rainy season, Mae Kuang irrigation project required highest amount of irrigation water expressed as Mm^3 of water, followed by Mae Taeng, Mae Ping Kao, and Mae Feag-Mae Ngad. However, in the dry season, the Mae Kuang irrigation project required the lowest quantity of irrigation water because most land was used for single crop of rice. Although Mae Ping Kao covered smallest irrigated areas but it required highest amount of water for irrigation in the dry season since longan was extensively planted followed by Mae Taeng irrigation project. However, the total amount of water required for the whole year was highest in Mae Kuang irrigation project due to its extent of the cultivated area (Figure 28), followed by Mae Ping Kao, Mae Taeng, and Mae Feag-Mae Ngad.



	Mae Taeng	Mae Feag-Mae Ngad	Mae Kuang	Mae Ping Kao
Rainy season	116.16	74.26	215.40	96.08
Dry season	142.92	116.59	107.64	167.08
All year	259.09	190.86	323.07	263.16

Figure 28 Total amount of irrigation water requirement (Mm^3) for all irrigation projects

4.5 Water productivity assessment

4.5.1 Water productivity of Mae Taeng irrigation project

The water productivity of Mae Taeng irrigation project was assessed only in agricultural areas. Spatial distribution of water productivity is shown in Figure 29. Different shades of green color represent the value of water productivity while the red color symbolizes the non-agricultural areas which were not assessed such as urban, forest, water resource, and miscellaneous areas.

Water productivity indicator is expressed as the ratio of net return (baht) to water supply (m^3). The areas having water productivity equal to 1 means one cubic meter of irrigation water can create net return value of one baht. Hence, high water productivity is desirable in the situation where water scarcity is evidenced and water must be used carefully managed. This can be done by improving water use efficiency or carefully select cropping systems which are suitable for land quality.

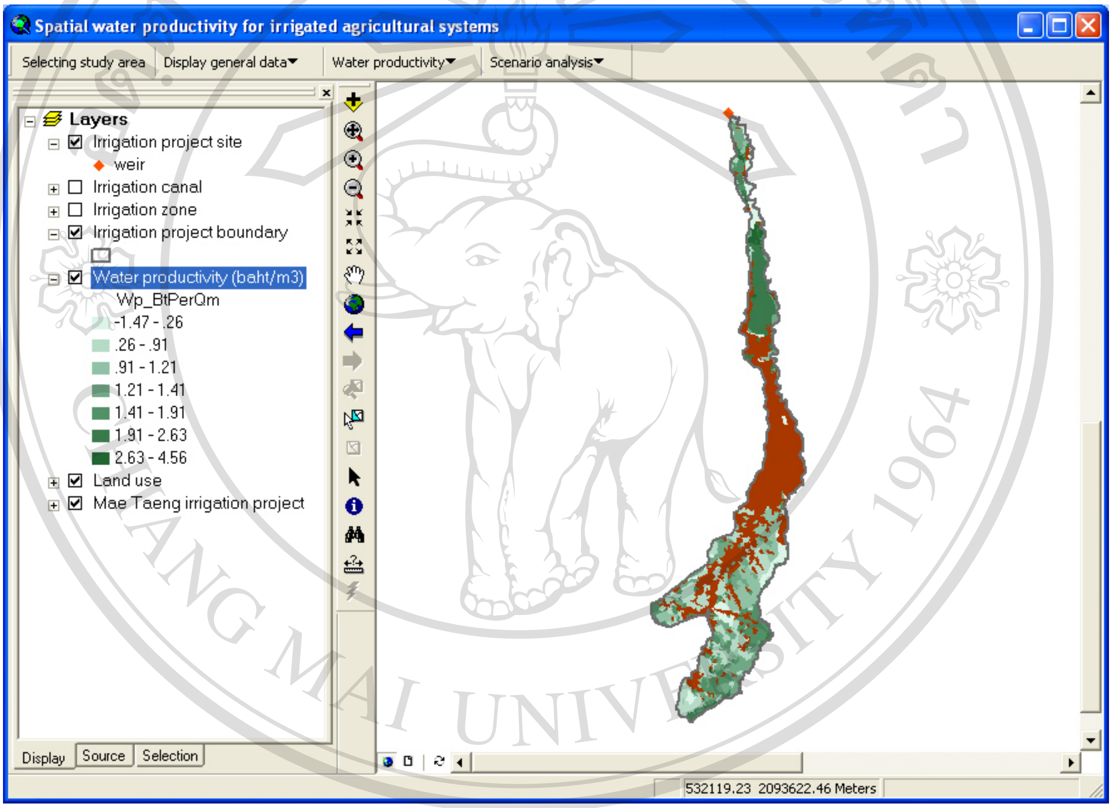


Figure 29 Spatial distribution of water productivity in Mae Taeng irrigation project

The detailed analysis of each cropping areas in Mae Taeng irrigation project reveals that water productivity of the project for all year round was 1.31 baht/m^3 (Table 8). The areas in the rainy season where main crop of paddy rice were grown generated water productivity of 1.01 baht/m^3. In the dry season, the second crop created higher water productivity than main season rice, particularly high-value such as vegetables and onion/garlic could yield water productivity of 6.44 and 3.29 baht/m^3 respectively.

The cropping systems which were proved to have high water productivity were rice+vegetable (2.76 baht/m^3), longan (1.56 baht/m^3), and rice+onion/garlic (1.45 baht/m^3).

Table 8 Water productivity of different cropping systems in Mae Taeng irrigation project

Land use	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Rice	5,960	35,269	56.05	61.55	0.91
Rice+Rice	426	5,660	7.99	7.02	1.14
Rice+Soybean	5,851	43,486	105.98	80.23	1.32
Rice+Vegetable	55	724	2.01	0.73	2.76
Rice+Onion/Garlic	2,219	60,273	50.09	34.53	1.45
Longan	4,205	27,607	131.42	84.47	1.56
Mixed orchard	273	1,513	6.66	5.86	1.14
Other cropping areas	124	487	1.58	1.50	1.05
Total	19,113	175,019	361.78	275.89	1.31

4.5.2 Water productivity of Mae Feag-Mae Ngad irrigation project

The Spatial distribution of water productivity in Mae Feag – Mae Ngad irrigation project is shown in Figure 29. The highest water productivity was found in the upper part of the Mae Feag irrigation project where double cropping of rice and high-value vegetables such as rice+potato and rice+vegetable cropping systems were practiced, their water productivity were 6.67 and 2.47 baht/m^3 respectively (Table 9). The main crop in the rainy season was rice cropping system covering about 8,000 ha and had water productivity of about 0.97 baht/m^3. In the dry season, the three main cropping areas were potato, rice, and onion/garlic could produce the net return value of about 67, 31, and 20 million baht respectively. In the area where double crops of rice were cultivated, water productivity was about 1.0 baht/m^3, the same as in the rainy season. The yearly water productivity of the Mae Feag – Mae Ngad irrigation project was about 1.23 baht/m^3.

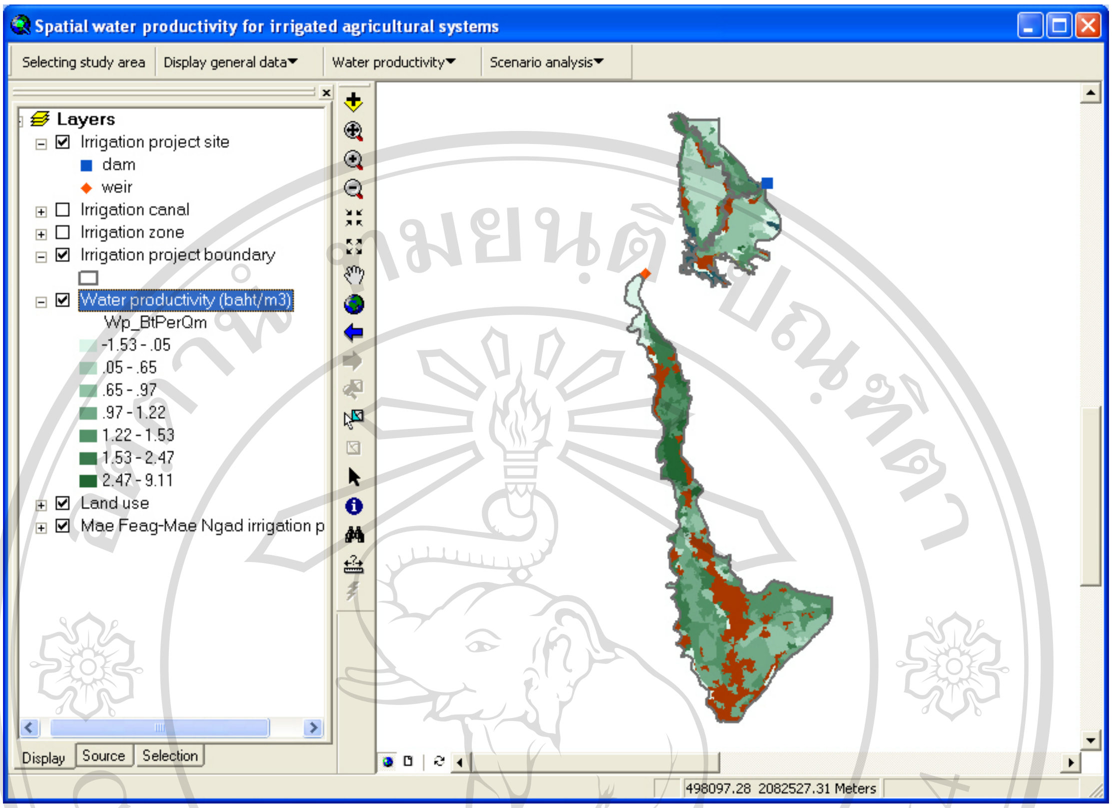


Figure 30 Spatial distribution of water productivity in Mae Feag-Mae Ngad irrigation project

Table 9 Water productivity of different cropping systems in Mae Feag-Mae Ngad irrigation project

Land use	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Rice	1,678	10,156	24.51	22.89	1.07
Rice+Rice	2,418	30,724	65.25	60.03	1.08
Rice+Soybean	2,038	16,945	24.94	50.81	0.49
Rice+Vegetable	11	233	0.61	0.25	2.47
Rice+Potato	577	12,813	76.42	11.46	6.67
Rice+Onion/Garlic	1,212	33,291	36.58	35.51	1.03
Longan	2,740	22,510	124.90	93.83	1.33
Mango/Longan	2,403	11,460	41.88	36.81	1.14
Other cropping areas	458	1,896	6.48	14.16	0.46
Total	13,535	140,028	401.57	325.75	1.23

4.5.3 Water productivity of Mae Kuang irrigation project

Relatively high water productivity was found in the upper part of the Mae Kuang irrigation project because of closeness to the reservoir and the cultivated land were allocated to double cropping (Figure 31). If the whole service area of the irrigation project was considered, water productivity was 2.76 baht/m^3. The paddy rice in rainy season had water productivity of 2.50 baht/m^3. It consumed 81 Mm^3 of water to generate the net return of about 203 million baht. In the dry season, water productivity of the land where vegetable and tobacco were grown after paddy rice were found to be 8.65 and 3.13 baht/m^3 respectively, while those of second rice and onion/garlic were 1.66 and 1.65 baht/m^3 respectively. On yearly basis, water productivity of rice+vegetable, mango/longan, rice+rice, and rice+soybean cropping systems were 6.49, 6.07, 2.81, and 2.78 baht/m^3 respectively (Table 10).

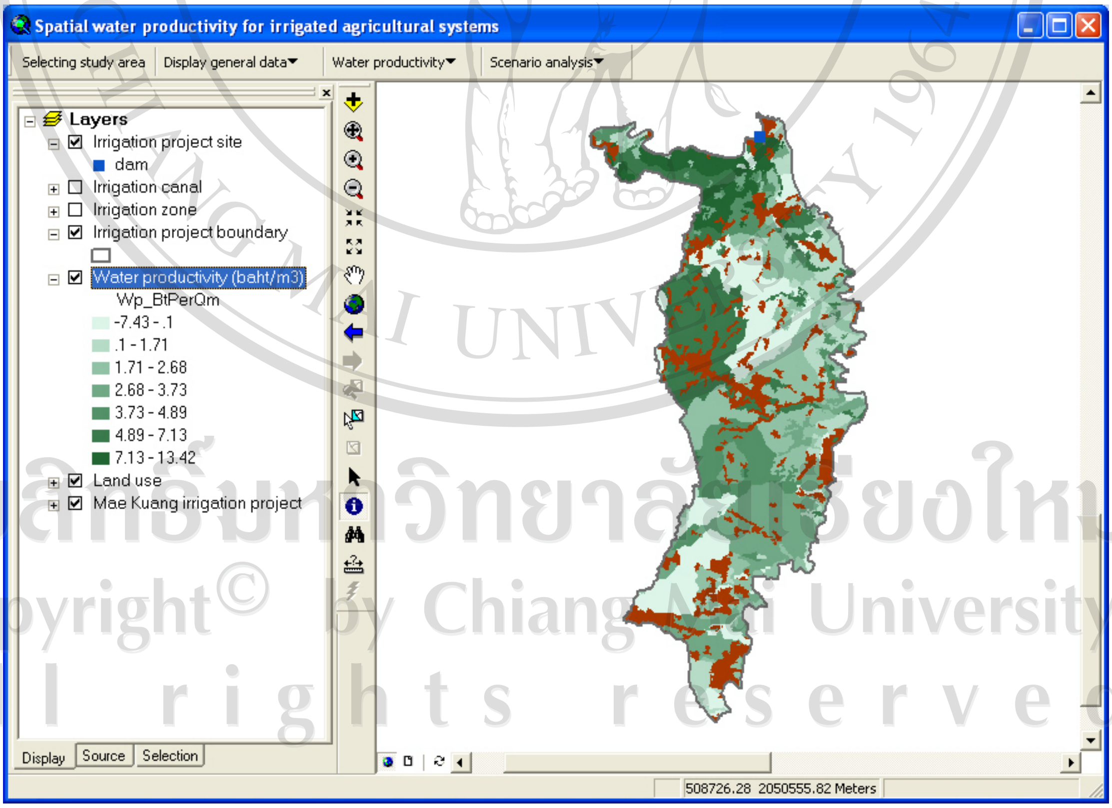


Figure 31 Spatial distribution of water productivity in Mae Kuang irrigation project

Table 10 Water productivity of different cropping systems in Mae Kuang irrigation project

Land use	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Rice	27,559	148,572	181.28	74.50	2.43
Rice+Rice	502	6,274	12.73	4.53	2.81
Rice+Soybean	412	2,697	7.30	2.63	2.77
Rice+Vegetable	68	1,476	3.56	0.55	6.49
Rice+Tobacco	1,264	9,026	27.36	9.80	2.79
Rice+Onion/Garlic	613	15,956	8.61	5.63	1.53
Longan	1,453	10,300	38.35	17.72	2.16
Mango/Longan	5,593	33,305	138.37	22.78	6.07
Other cropping areas	2,457	11,460	45.32	29.74	1.52
Total	39,921	239,066	462.88	167.88	2.76

4.5.4 Water productivity of Mae Ping Kao irrigation project

In Mae Ping Kao irrigation project, water productivity of the eastern zone was relatively high comparing to the rest of the areas (Figure 32). In general, water productivity of the project was 3.87 baht/m^3. The longan production that covered about 7,200 ha or 75 percent of irrigated areas greatly contributed to the net return of about 330 million baht while consuming about 80 Mm^3 of irrigation water (Table 11). Other cropping systems such as single crop of rice and double rice cropping systems grown in this irrigation project could generate higher water productivity (about 2.05 and 2.23 baht/m^3) than the same cropping systems found in other irrigation projects reflecting the higher irrigation project efficiency.

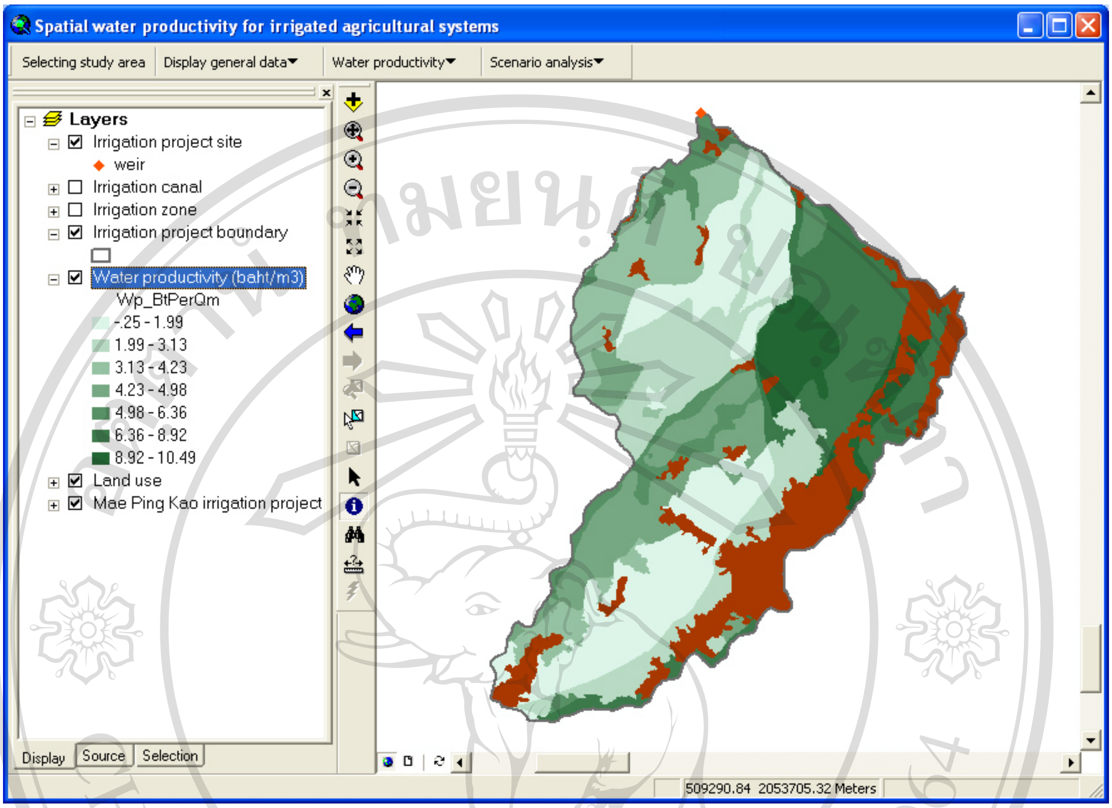


Figure 32 Spatial distribution of water productivity in Mae Ping Kao irrigation project

Table 11 Water productivity of different cropping systems in Mae Ping Kao irrigation project

Land use	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Rice	716	4,477	3.36	1.64	2.05
Rice+Rice	1,406	18,561	19.82	8.89	2.23
Rice+Soybean	38	293	0.45	0.39	1.16
Rice+Vegetable	12	248	0.54	0.15	3.51
Longan	7,225	58,257	328.93	80.12	4.11
Total	9,397	81,836	353.10	91.19	3.87

4.5.5 Water productivity of all irrigation projects

Comparison of water productivity at the project level among four large irrigation projects in Chiang Mai – Lamphun valley (Figure 33) revealed that water productivity the Mae Ping Kao was highest (3.87 baht/m^3), followed by Mae Kuang (2.76 baht/m^3), and Mae Taeng (1.31 baht/m^3). The lowest water productivity was 1.23 baht/m^3 for Mae Feag-Mae Ngad (Table 12).

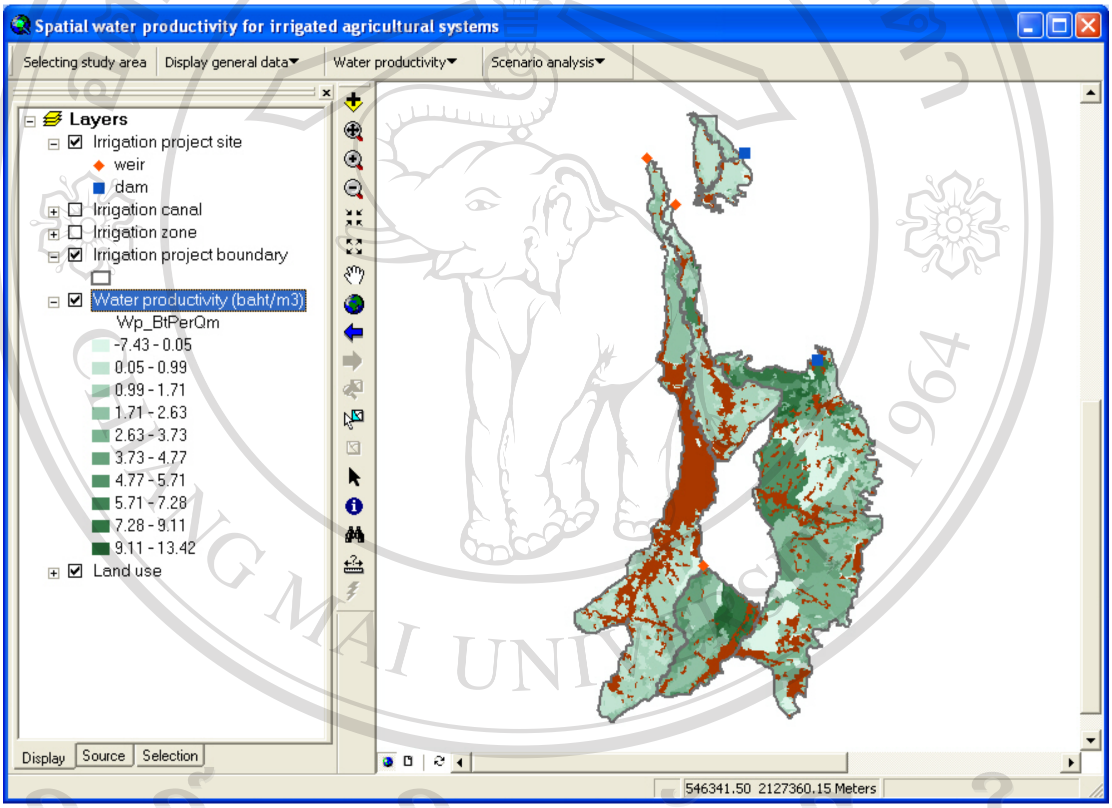


Figure 33 Spatial distribution of yearly water productivity (baht/m^3) in all irrigation projects

Table 12 Water productivity of all irrigation projects

Irrigation project name	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Mae Taeng	19,113	175,019	361.78	275.89	1.31
Mae Feag-Mae Ngad	13,535	140,028	401.57	325.75	1.23
Mae Kuang	39,921	239,066	462.88	167.88	2.76
Mae Ping Kao	9,397	81,836	353.10	91.19	3.87

Two factors may contribute to the high value of water productivity in Mae Ping Kao irrigation project, crop production system and better water management. In this project high net return of agricultural activities derived from longan production which occupies about 75 percent of irrigated area. Better water management of the system was achieved from the compactness of the service area which in turn resulted in the shorter canal networks hence lower conveyance loss and high irrigation efficiency. Since irrigation water requirement in this study was estimated from water distribution by the irrigation project, additional water supply to the farms from tube wells which were not included in the estimation of irrigation water requirement due to unavailability of data may also contributed to the high value of water productivity in Mae Ping Kao.

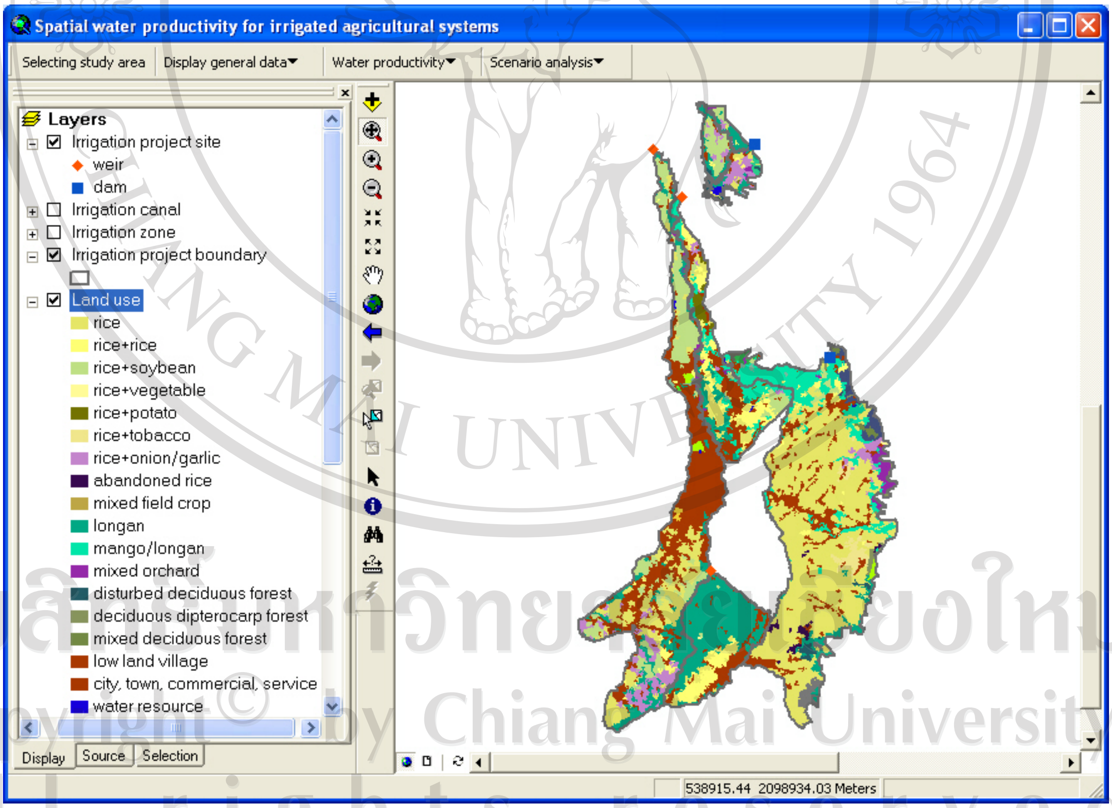


Figure 34 Land use of all irrigation projects (Sangchyoswat *et al.*, 2005)

At the time of this study Mae Kuang irrigation project was recently complete and the reservoir was unfilled to its capacity. Overall water productivity on the annual basis was 2.76 baht/m^3, water was used for supplementing irrigation to the main season paddy rice while it was adequate for applying to the dry season crops (Figure 41). However, it is expected that overall water productivity will be improved in the future when the reservoir is up to its capacity and proper land use planning is exercised.

The low value of water productivity (1.31 baht/m^3) in Mae Taeng was caused by the unproductive land in the middle part of the project where conversion of agricultural land to urban areas occurred. Low water conveyance efficiency in the main canal which is 75 km long and in the lateral canals also induced low irrigation efficiency and further decreased water productivity in this irrigation system. Although Mae Feag-Mae Ngad irrigation project generated higher net return from cropping activities than Mae Taeng irrigation project but during the study period the project overly supplied irrigation water hence reducing its water productivity to 1.23 baht/m^3.

4.5.6 Water productivity of rice cropping system

The comparison of water productivity for rice growing areas in the rainy season among different irrigation projects (Table 13 and Figure 35) suggested that Mae Kuang irrigation project had largest rice areas (about 30,000 ha) and highest water productivity (2.50 baht/m^3). Although Mae Ping Kao irrigation project had smallest rice areas (about 2,000 ha) but water productivity was higher than other projects (about 2.01 baht/m^3) because of higher irrigation efficiency in both irrigation projects consequently low water consumption. Although Mae Taeng and Mae Feag-Mae Ngad irrigation projects generated high net return per area (about 10,000 and 14,000 bath/ha) but irrigation water was over supplied resulting in water productivity of about 1.01 and 0.97 baht/m^3.

Table 13 Water productivity of rice cropping systems in the rainy season

Irrigation project name	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Mae Taeng	14,511	83,412	149.39	147.76	1.01
Mae Feag-Mae Ngad	7,934	48,257	111.16	114.23	0.97
Mae Kuang	30,417	165,427	203.58	81.35	2.50
Mae Ping Kao	2,172	13,625	10.50	5.22	2.01

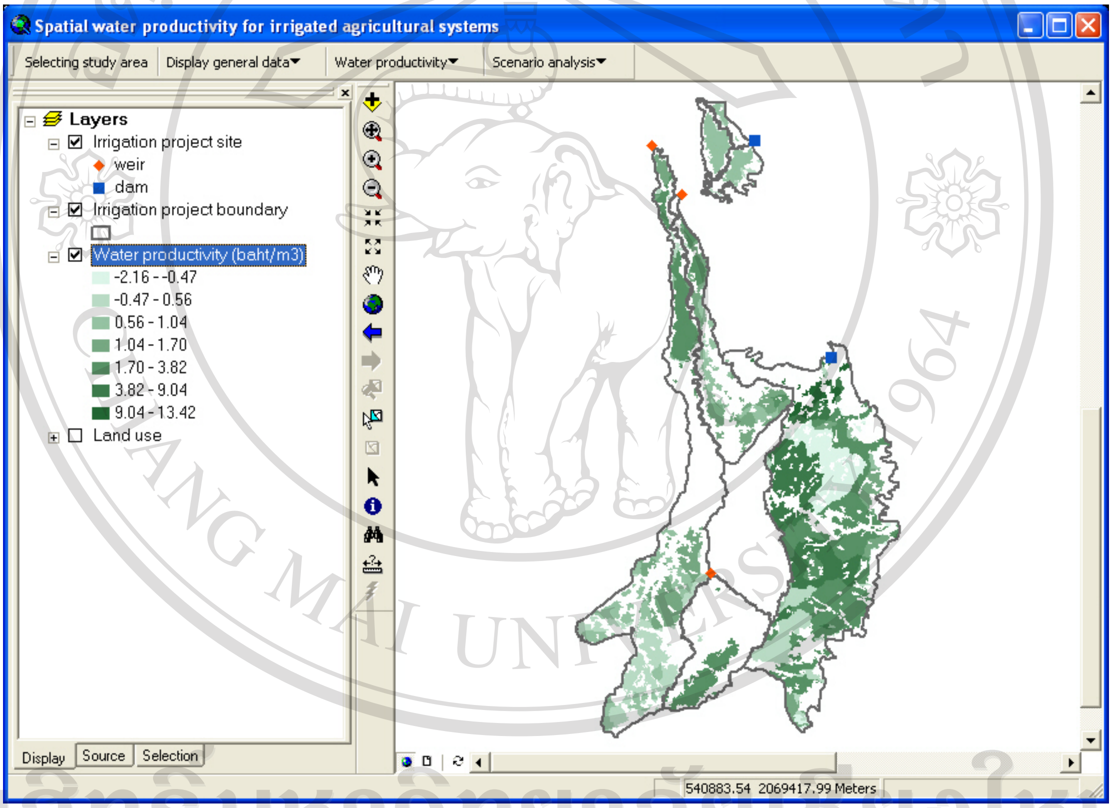


Figure 35 Spatial distribution of water productivity in rice cropping system

4.5.7 Water productivity of second rice cropping system

Water productivity assessment in second rice cropping areas in the dry season (Table 13 and 14) revealed that most irrigation projects yielded higher water productivity than that of the rainy period as the consequence of increasing yield and net return per unit area, couple with effective water use.

Water productivity for this condition in Mae Ping Kao, Mae Taeng, Mae Kuang, and Mae Feag-Mae Ngad irrigation projects were 2.31, 1.88, 1.66, and 1.03 baht/m^3 respectively. The large areas of second rice cropping system was found in Mae Feag-Mae Ngad and Mae Ping Kao irrigation project because of their reliable water supply while irrigation water was limited in Mae Taeng and Mae Kuang irrigation projects (Figure 36). This situation constrained the farmer from selecting second crop of rice as their crop choice.

Table 14 Water productivity of second rice cropping systems in the dry season

Irrigation project name	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Mae Taeng	426	3,026	4.88	2.60	1.88
Mae Feag-Mae Ngad	2,418	16,194	31.21	30.31	1.03
Mae Kuang	502	3,269	6.02	3.63	1.66
Mae Ping Kao	1,406	9,684	12.87	5.58	2.31

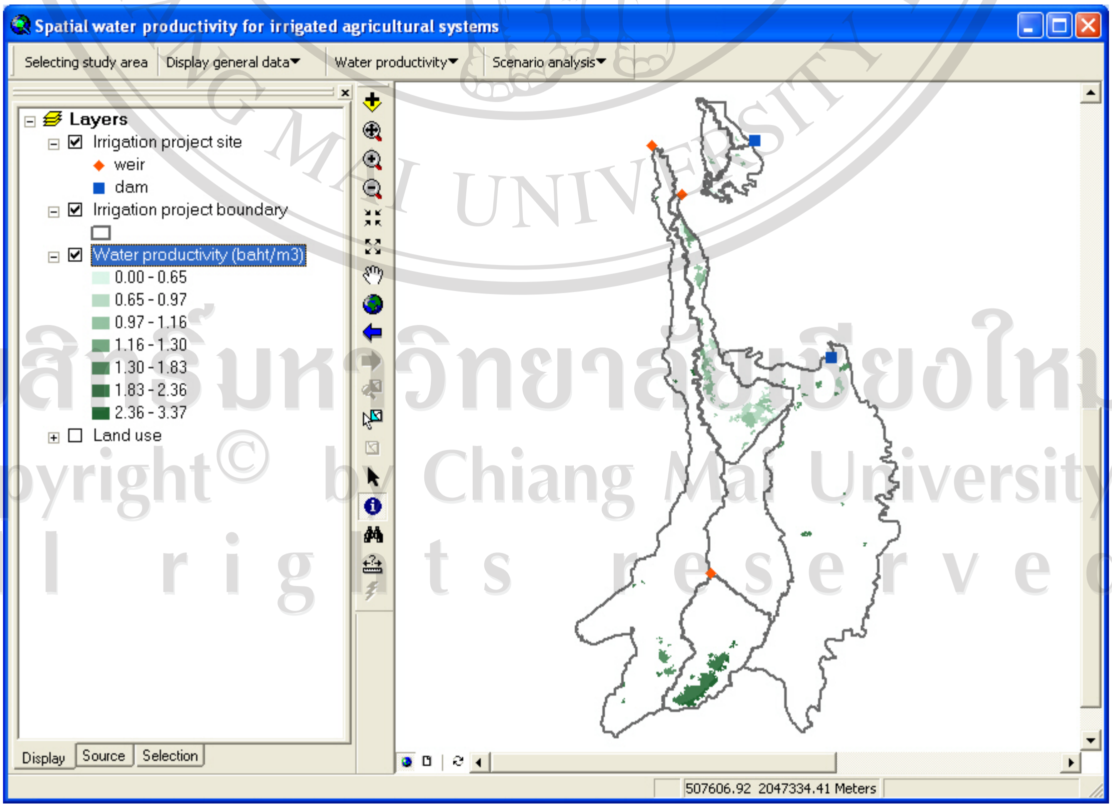


Figure 36 Spatial distribution of water productivity in second rice cropping system

4.5.8 Water productivity of longan cropping system

The main longan plantation areas were found in Mae Ping Kao and the lower part of Mae Taeng irrigation project. When comparing water productivity of longan cropping system across all irrigation projects (Table 15 and Figure 37), it was found that water productivity of Mae Ping Kao irrigation project was the highest (4.11 baht/m^3) due to high irrigation efficiency and high crop productivity followed by Mae Kuang (2.16 baht/m^3) Mae Taeng (1.56 baht/m^3) and Mae Feag-Mae Ngad (1.33 baht/m^3).

Table 15 Water productivity of longan cropping system

Irrigation project name	Area (ha)	Yield (ton)	Net return (M baht)	Water consumed (M m^3)	WP (baht/m^3)
Mae Taeng	4,205	27,607	131.42	84.47	1.56
Mae Feag-Mae Ngad	2,740	22,510	124.90	93.83	1.33
Mae Kuang	1,453	10,300	38.35	17.72	2.16
Mae Ping Kao	7,225	58,257	328.93	80.12	4.11

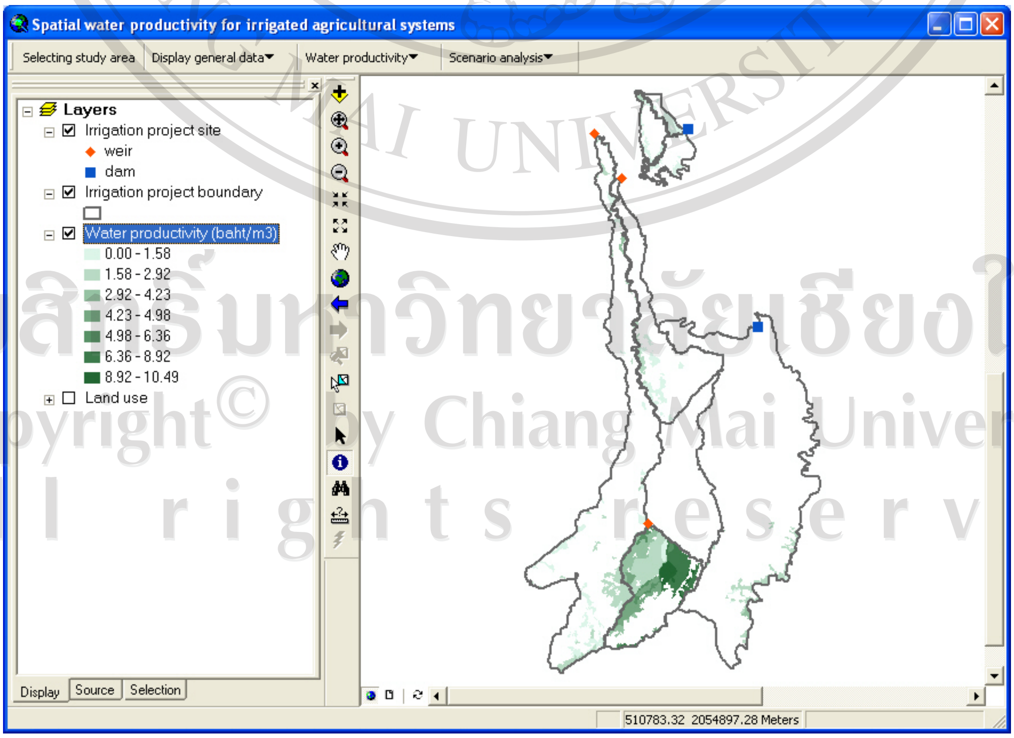


Figure 37 Spatial distribution of water productivity in longan cropping system

4.6 Scenario analysis

The purpose of scenario analysis was to evaluate the effects of changing land use, water supply and input costs and output price on water requirement and water productivity of the target areas. The results will provide useful information for land use planners and water resource manager to prepare a suitable guideline to cope with the changing situations.

4.6.1 Land use change analysis

One of the most likely situations that will occur in the future of Chiang Mai-Lamphun valley would be the reducing price of garlic due to the trade agreement, encouraging farmers to find alternative crop to substitute garlic. This situation of changing land use pattern was simulated by replacing rice+onion/garlic areas in Mae Taeng irrigation project with rice+soybean cropping system (Figure 38).

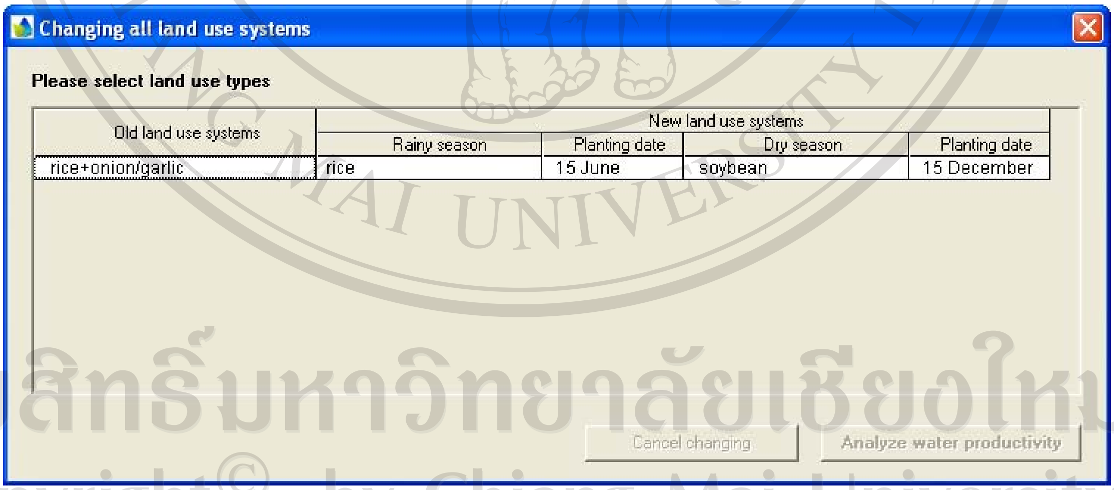


Figure 38 Setting parameter for changing land use pattern from rice+onion/garlic to rice+soybean

The result of this simulation revealed that the areas of replacement were about 2,219 ha, water requirement in replacement areas was reduced from 34.53 to 28.58 Mm^3 because soybean water requirement was about 748 mm comparing to 1,016 mm of onion/garlic. However, this simulation used the prices of soybean, onion, and garlic in 2000 as parameters that were set at 11.28, 4.58, and 5.54 baht/kg respectively. Net return for the replacement areas during the dry season was reduced from 50.09 to 40.18 million baht and water productivity in replacement areas were reduced from 1.45 to 1.41 baht/m^3.

4.6.2 Water supply and economic factors change analysis

The effects of changing in water supply, inputs cost and output price can be evaluated from scenario analysis tools. In this situation, total water supply was reduced to 95 percent compare with that in 2000, cost of inputs was reduced to 95 percent, and output prices were increased to 120 percent (Figure 39).

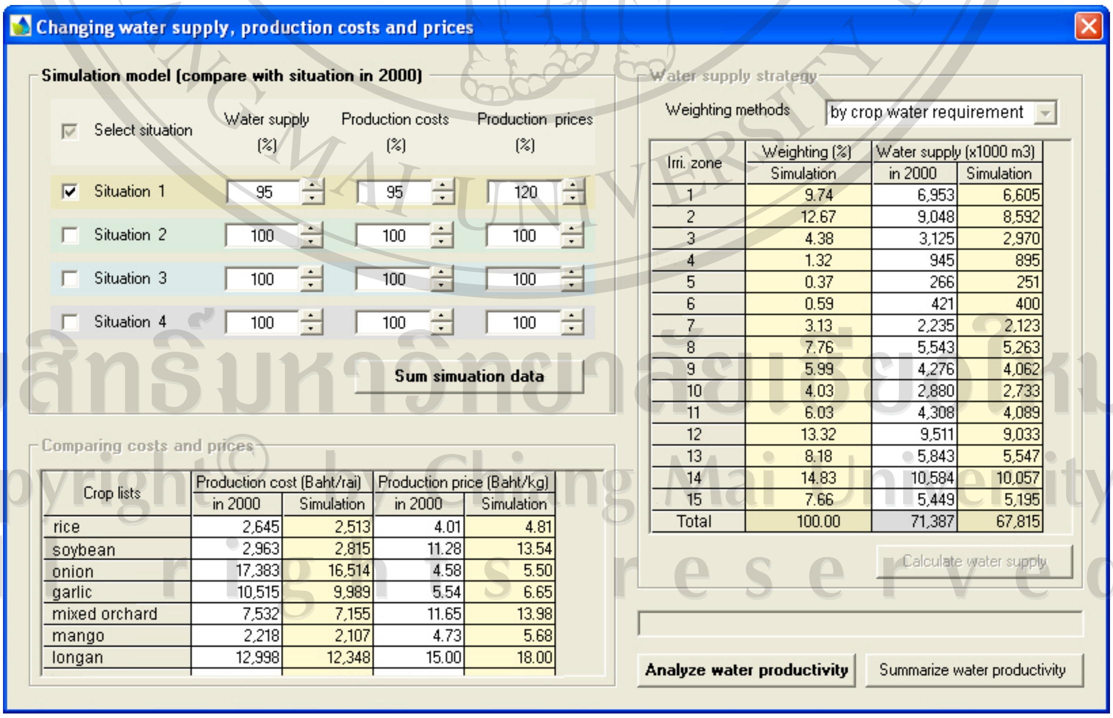


Figure 39 Setting parameter to evaluate effects of changing water supply and economic factors on water productivity

The estimated cost of inputs and output price of the situation in 2000 and by simulation were shown in the lower left frame of Figure 39. The strategy for water allocation in the right frame was set to supply irrigation water according to crop water requirement in each irrigation zone. The water supply was reduced from 71.39 to 67.82 Mm^3. The net return was increased from 83.54 to 190.50 million baht. The results from this analysis suggested that water productivity in the dry season of Mae Taeng irrigation project would increase to 2.81 baht/m^3 (Figure 40) comparing to 1.17 baht/m^3 in year 2000.

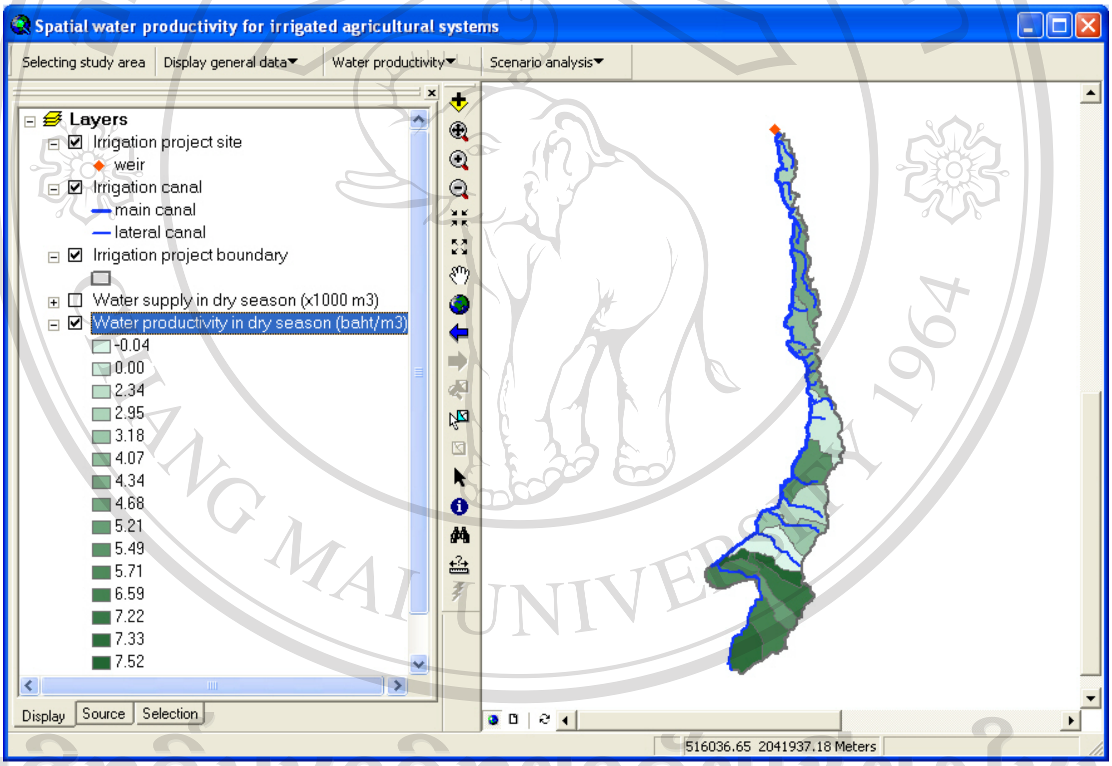


Figure 40 Spatial distribution of zonal water productivity from simulation