MAHAWELI WATER SECURITY INVESTMENT PROGRAM

PROJECT PREPARATORY TECHNICAL ASSISTANCE

TA-8633

ECONOMIC ASSESSMENT

JUNE 2015

ABBREVIATIONS

ADB	–	Asian Development Bank
CI	–	cropping intensity
DMI	–	domestic, municipal and industrial
EIRR	–	economic internal rate of return
ENPV	–	economic net present value
EOCC	–	economic opportunity cost of capital
GDP	–	gross domestic product
GWh	–	gigawatt hour
KMTC	–	Kaluganga-Moragahakanda Transfer Canal
MASL	–	Mahaweli Authority of Sri Lanka
MCB	–	Mahaweli Consultancy Bureau
MCM	–	million cubic meter
MDP	–	Mahaweli Development Program
MFF	–	multitranche financing facility
MLBCRP	–	Minipe Left Bank Canal Rehabilitation Project
MMDE	–	Ministry of Mahaweli Development and Environment
NCPCP	–	North Central Province Canal Program
NWPCP	–	North Western Province Canal Project
O&M	–	operations and maintenance
OFC	–	other food crop
PPTA	–	project preparatory technical assistance
SCF	–	standard conversion factor
SLRs	–	Sri Lankan Rupees
SWRF	–	shadow wage rate factor
UECP	–	Upper Elahera Canal Project
WOP	–	without project
WP	–	with project

CONTENTS

Page

I.	INTRODUCTION	1
II.	ECONOMIC RATIONALE	1
III.	METHODOLOGY AND DATA	2
	A. Economic Costs	5
	B. Economic Benefits	6
IV.	RESULTS	18
V.	DISTRIBUTION AND POVERTY ANALYSIS	19

ANNEXES

Annex 1: Relationship between Irrigation and Paddy Yields
Annex 2: Assumed Increase in Cropping Intensities by Sub-area
Annex 3: Identifying the Impact of Improved Irrigation on Paddy Yield: An Econometric Analysis

TABLES

Table 1: Estimation of Farm Gate Prices for Internationally Traded Commodities	3
Table 2: Estimation of Standard Conversion Factor	4
Table 3: Economic and Financial Prices of Agricultural Inputs and Outputs	4
Table 4: Economic Investment Cost of NCPCP, 2015-2029	6
Table 5: Current and Projected Cropping Intensities in the Agricultural Benefit Area	8
Table 6: Harvested Area and Agricultural Production, 2030	10
Table 7: Results of Discounted Economic Surplus Analysis	11
Table 8: Principal Source of Drinking Water in DMI Benefit Area, 2012	12
Table 9: Parameters Used For Quantifying Economic Benefits of Water Supply	14
Table 10: Construction Cost of Selected Piped Water Supply Systems	14
Table 11: Electricity Generation by Source, 2008-2012	16
Table 12: Composition of Quantifiable Economic Benefits of NCPCP	18
Table 13: Sensitivity of Project EIRR to Changes in Selected Variables a	18
Table 14: Distribution of Project Benefits	19

FIGURES

Figure 1: Coverage Rates of Piped Water Supply in DMI Benefit Area, 2020-2060	16

I. INTRODUCTION

1. **Scope.** This supplementary appendix contains a detailed analysis of the economic costs and benefits of the North Central Province Canal Project (NCPCP). The first phase of this project involves the Minipe Left Bank Canal Rehabilitation Project (MLBCRP), the construction of the Northwest Province Canal Project (NWPCP), and the construction of the Upper Elahera Canal Project (UECP) which includes the Kaluganga-Moragahakanda Transfer Canal (KMTC). These first phase investments will be co-financed from the proceeds of ADB's proposed multitranche financing facility (MFF) for the Mahaweli Water Security Improvement Program.[1] The construction of the KMTC and UEC, which account for about two-thirds of the cost of Phase 1, is needed to implement Phase 2 of the NCPCP. This second phase mainly consists of the construction of the Kalinganuwara Pumping Station, the Lower Uma Oya, the Randenigala-Kaluganga Transfer Canal and the North Central Province Canal. Because the infrastructure to be financed by the MFF is needed to realize economic benefits that will accrue upon completion of the Phase 2 investments (and is indeed designed at the scale that is required to realize these benefits), the economic analysis presented here covers the entire NCPCP, instead of the part that will be co-financed by the MFF.

2. **Structure.** The remainder of this supplementary appendix is structured as follows. Section II validates the economic rationale of undertaking NCPCP. Section III first gives an overview of the methodology that was used to estimate the economic costs and benefits of It then presents estimates of investment costs and incremental O&M costs, expressed in economic prices, followed by estimates of quantifiable economic benefits from: (i) increased agricultural production, (ii) increased provision of raw water for domestic, municipal and industrial (DMI) uses, and (iii) increased hydropower generation. Section III also discusses economic benefits that cannot be quantified accurately because of methodological difficulties. Section IV compares quantifiable economic cost and benefits, and presents sensitivity analyses. Section V contains a distribution and poverty analysis.

II. ECONOMIC RATIONALE

3. **Macroeconomic assessment.** Since the end of the civil war in 2009, Sri Lanka has witnessed rapid economic growth. From 2010 to 2013, GDP increased by over 7% per annum in real terms. The poverty head count dropped from 15.2% in 2006/07 to 6.5% in 2012. From 2009 to 2013, the share of the agricultural sector dropped from 12.0% to 10.8% of real GDP. Nonetheless, the agricultural sector continues to employ over 30% of the nation's labor force, a percentage that has remained stable since 2000. The agricultural sector therefore remains important to the Sri Lankan economy, both in terms of economic outputs and employment. The sector is especially important in the central and northern provinces, where it accounts for 20-25% of regional GDP and employs over 50% of the labor force.[2]

4. **Demand analysis.** At present, over 50% of the population in the NCPCP's beneficiary area is dependent on irrigated agriculture. Cropping intensities in existing cultivated areas are suppressed, mainly because of persistent water shortages. There is consequently a strong demand by farmers for additional irrigation water to increase agriculture production, which currently mostly consists of paddy, and allow the cultivation of higher value-added crops. The project would also help to improve food security in the area, which is lower than in most other parts

[1] Previously called "Water Resources Development Investment Program".
[2] *Economic and Social Statistics of Sri Lanka 2014*. Central Bank or Sri Lanka.

of Sri Lanka. Given the limited agriculture production and food insecurity status of the project area, a strong local demand is anticipated for the additional agriculture production generated by the project.

5. **Rationale.** The NCPCP will improve deliveries of irrigation water and provide raw water to water utilities and hydropower plants. These are private goods that can, in principle, be delivered to individual customers. However, because farmers are presently exempt from paying irrigation water charges, it is not possible for the private sector to undertake the project on a financially profitable basis. Without some form of public intervention, the market will construct no (or fewer) irrigation water infrastructure than is optimal from a societal point of view. To address this market failure, government intervention is proposed in the form of capital grants and—to the extent required—O&M subsidies.

6. **Project alternatives.** The proposed NCPCP is the least-cost option that was identified to achieve the objective of providing water to the project area whilst minimizing adverse impacts on the existing system and the environment. A large number of studies and simulations were undertaken to select the infrastructure that would best achieve this objective. The main reasons for choosing the selected option can be summarized as follows:[3]

(i) shortest transfer route length compared to alternative options studied,
(ii) least environmental damage compared to alternative options studied,
(iii) optimization of infrastructure to be developed under the Moragahakanda and Kaluganga Reservoir projects which are currently under construction, and
(iv) enhanced flexibility with regard to regulation of flows.

III. METHODOLOGY AND DATA

7. **Overview.** An economic analysis of was prepared for NCPCP in accordance with ADB's *Guidelines for the Economic Analysis of Projects* (1997). The guidelines describe four basic steps to analyzing the economic viability of a project. These steps are:

(i) identify economic costs and benefits
(ii) quantify economic costs and benefits (comparing with-project and without-project situations for each alternative)
(iii) value economic costs and benefits
(iv) compare benefits and costs

8. **Identification and quantification of economic costs and benefits.** The project's incremental economic costs and benefits were identified and (to the extent possible) quantified for the period 2015-2060 (30-year implementation period from completion of Phase 2). All costs and benefits were expressed in mid-2014 economic prices including physical contingencies, but excluding transfer payments (such as taxes, duties and subsidies). The economic cost-benefit analysis was conducted at the domestic price level (domestic price numeraire).

9. **Valuation of economic costs and benefits.** For internationally traded inputs and outputs, economic prices (at farm gate) were derived from international border prices adjusted for the cost of transportation, handling, processing and packing (Table 1). For non-traded inputs and outputs, financial prices were obtained from local markets and converted into economic prices using the standard conversion factor (see Table 2 for an estimation of the SCF). The

[3] For details, refer to *Pre-Feasibility Study for the Implementation of North Central Province Canal* (MCB, 2012).

economic price of farm labor was estimated by applying a shadow wage rate factor (SWRF) of 0.7 to the financial price of this input. For an overview of economic and financial prices of agricultural inputs and outputs used in this analysis, see Table 3.

10. **Comparison of economic benefits and costs.** A project is deemed economically feasible if the economic net present value (ENPV) of the project's discounted (net) benefit streams is at least zero, or if economic internal rate of return (EIRR) of these benefit streams exceeds the economic opportunity cost of capital (EOCC) that was employed to finance the project. For the purpose of assessing the economic viability of the project, the assumed EOCC was 12%.[4]

Table 1: Estimation of Farm Gate Prices for Internationally Traded Commodities

Item	Rice	Sugar	Urea	TSO	Potash
International commodity rate ($/ton)*	435	380	316	413	287
Adjustment factor**	1.43	5.00	1.00	1.00	1.00
Adjusted price ($/ton)	305	76	316	413	287
Freight and insurance ($/ton)	30	8	32	41	29
Conversion rate (SLRs/$)***	130	130	130	130	130
CIF Colombo price (SLRs)	43,618	10,883	45,308	59,141	41,098
Handling and transport from Colombo (SLRs)	3,053	762	3,172	4,140	2,877
Price at project area (SLRs)	46,671	11,645	48,479	63,281	43,975
less: processing/packing charges (SLRs)	1,400	349	-	-	-
less: transport farm to market (SLRs)	700	1,747	727	949	660
Farm gate price (SLRs)	**44,571**	**9,549**	**47,752**	**62,331**	**43,315**
Item	**Ground Nuts**	**Maize**	**Dry Chillies**	**Green Gram**	**Big Onion**
International commodity rate ($/ton)*	1,276	257	1,173	1,230	333
Adjustment factor**	1.02	1.02	1.02	1.02	1.02
Adjusted price ($/ton)	1,251	252	1,150	1,206	326
Freight and insurance ($/ton)	125	25	115	121	33
Conversion rate (SLRs/$)***	130	130	130	130	130
CIF Colombo price (SLRs)	179,138	36,100	164,660	172,660	46,750
Handling and transport from Colombo (SLRs)	12,540	2,527	11,526	12,086	3,273
Price at project area (SLRs)	191,678	38,627	176,186	184,746	50,023
less: processing/packing charges (SLRs)	5,750	1,159	5,286	5,542	1,501
less: transport farm to market (SLRs)	2,875	579	2,643	2,771	750
Farm gate price (SLRs)	**183,052**	**36,889**	**168,258**	**176,433**	**47,771**

* Source: World Bank Pink Sheets (Q3-2014), except big onion, dry chillies, maize and green gram (CIF Colombo prices taken from Harti Monthly Food Bulletin, August 2014)

** Adjustment factor of 1.02 applied to ground nuts, maize, dry chillies, green gram and big onion to correct for differences in quantity and quality. Adjustment factor of 1.43 used for rice to enable comparison with paddy (which contains husk). Adjustment factor of 5.00 used for sugar to enable comparison with sugar cane.

*** As of 1 July 2014.

[4] The *Guidelines for the Economic Analysis of Projects* state that "The Bank would expect to…accept independent projects and subprojects with an EIRR between 10 and 12% for which additional unvalued benefits can be demonstrated, and where they are expected to exceed unvalued costs".

Table 2: Estimation of Standard Conversion Factor
(SLRs billion)

		2009	2010	2011	2012	Average
Total imports	M	814	974	1,168	1,246	1,050
Total exports	X	1,173	1,520	2,241	2,441	1,844
Import duties*	D	177	179	205	240	200
Sales tax on imports	T	68	100	121	120	102
Subsidies on imports	S	27	26	30	36	30
Export duties	E	2	2	3	3	2
Export rebates	R	-	-	-	-	-
SCF**		**0.90**	**0.91**	**0.92**	**0.92**	**0.91**

Source: ADB, based on Central Bank of Sri Lanka (2014)
* Sum of import duties, import cess levies, ports and airport levy, nation building tax and special commodity levy
** Computed as (M+X) / [(M+T_M) + (X-T_X)], where M: CIF value of imports, X: = FOB value of exports, T_M: net value of taxes on imports (Tm=D+T-S), T_X : net value of taxes on exports (T_X = E-R).

Table 3: Economic and Financial Prices of Agricultural Inputs and Outputs
(SLRs)

Investment Cost Item	Unit	Economic Price	Financial Price*	Conversion Factor**
Tradable Outputs				
Paddy	kg	44.6	33.9	1.31
Maize	kg	36.9	33.3	1.11
Dry chillies	kg	168.3	150.0	1.12
Green gram	kg	176.4	196.3	0.90
Ground nut	kg	183.1	136.4	1.34
Big onion	kg	47.8	46.8	1.02
Sugarcane	kg	9.5	3.4	2.84
Non-Tradable Outputs				
Banana	kg	48.6	53.1	0.91
Vegetables	kg	25.4	27.7	0.91
Tradable Inputs				
Fertilizer for paddy	kg	48.9***	7.0	6.98
Fertilizer for other agricultural produce	kg	48.9***	25.0	1.96
Non-Tradable Inputs				
Farm labor	day	420	600	0.70
Other non-tradable inputs	(varies by type of input)			0.91

Source: ADB, based on World Bank (104), MCB (2012) and Harti Monthly Food Bulletin (August 2014)
* Financial prices of outputs computed based on average market prices in dry zone (Q4-2013 to Q3-2014).
** Economic Price / Financial Price (implied or directly estimated)
*** Weighted average for urea, TSP and potash (weight computed from import volumes during 2009-2012.

A. Economic Costs

11. **Types of economic costs.** An assessment of the economic costs and benefits of a project should only consider costs and benefits that would not arise without that project. The incremental economic costs of the proposed NCPCP consist of the project's:

(i) incremental economic investment cost of Phase 1 and Phase 2 infrastructure
(ii) incremental economic cost of operations and maintenance (O&M) of this infrastructure during the project's economic lifetime

The economic cost of adverse social impacts was not estimated separately, because the economic investment cost already includes the cost of compensating affected persons for economic losses caused by the project.[5] The economic cost of adverse environmental impacts was deemed negligible, and the economic investment cost also already contains a provision for environmental mitigation.

12. **Incremental economic investment cost.** This cost consists of the investment cost of the proposed infrastructure for NCPCP, including project management costs, and the cost of environment and social mitigation. The total economic investment cost of NCPCP was estimated at SLRs 202 billion (or approximately $1.55 billion), of which 35% for Phase 1 and the remaining 65% for Phase 2 (Table 4). As described in para 9, all economic costs are expressed in mid-2014 economic prices including physical contingencies. Phase 1 investments will be undertaken during 2015-2024, and the cost of these investments was based on detailed estimates prepared by the Ministry of Mahaweli Development and Environment (MMDE) and adjusted based on reviews by ADB.[6] Phase 2 investments are scheduled for 2015-2017 (Kalinganuwara Pumping Station) and 2020-2029 (other Phase 2 investments). The cost of these investments was based on indicative estimates presented in a pre-feasibility study that was prepared by the Mahaweli Consultancy Bureau (MCB) for MMDE in 2012.[7] The investment cost of both phases includes an allocation for the cost of rehabilitating minor tanks, to ensure that the benefits from the primary irrigation infrastructure accrue to the intended beneficiaries. As mentioned in paragraph 4, the economic lifetime of the project was conservatively estimated at 30 years from completion of the construction of Phase 2 investments. To reflect the benefits that may accrue after the end of the project's economic lifetime in 2060, the residual value of the project was set at 20% of the economic investment cost.

13. **Incremental economic O&M cost.** This is the incremental cost of two items:

(i) **Routine O&M.** This cost mainly consists of pumping costs and the cost of cleaning and minor repairs of project assets. Pumping costs were estimated at 1% per year of the economic investment cost. The annual cost of other routine O&M costs was estimated at 0.5% of the economic investment cost, but does not include incremental O&M costs that will be borne by farmers (which will be taken into account when estimating net economic benefits from increased agricultural production). The O&M cost estimates were verified with MMDE, and are broadly in line with estimates in MCB's pre-feasibility study of 2012.

---

[5] An alternative approach is to estimate economic losses to affected persons separately, and to treat compensation payments as transfer payments. This exercise would, in all likelihood, have a very similar impact on the net economic benefits of the project, but was not undertaken because resettlement and compensation costs account for less than 0.4% of the total project cost and were therefore not material.

[6] Previously called Ministry of Irrigation and Water Resources Management

[7] *Economic Analysis in Financial and Economic Terms of the North Central Province Canal Project of Mahaweli Development Program* (MCB, 2012). The Phase 2 investment costs presented in the study were converted into mid-2014 economic prices, assuming that the cost structure of these investments were the same as in Phase 1.

(ii) **Replacement.** The economic lifetime of canals, dams and other civil structures is similar to the economic lifetime of NCPCP (30-40 years). This is not the case, however, for hydraulic steel structures and mechanical equipment, which have an estimated economic lifetime of 20-25 years. The replacement cost of these items was estimated at 10% of the economic investment cost, and replacement was assumed to take place once during the project's economic lifetime, in 2050.

Table 4: Economic Investment Cost of NCPCP, 2015-2029
(constant mid-2014 prices)

Investment Cost Item	Construction Period	SLRs (bn)*	%Total
PHASE 1		**71.4**	**35**
MLBCRP	2015-2019	2.8	1
NWPCP	2015-2022	15.3	8
UECP	2015-2024	46.3	23
Other**	2015-2024	7.0	3
PHASE 2*		**130.4**	**65**
Kalinganuwara Pumping Station	2015-2019	24.9	12
Other Phase 2 investments	2020-2029	105.5	52
TOTAL		**201.8**	**100**

Source: ADB, based on MCB (2012)
* Project management, capacity building, environmental mitigation, social mitigation
** Includes the cost of project management and environmental and social mitigation

B. Economic Benefits

14. **Types of economic benefits.** The NCPCP will finance investments in infrastructure that will enable the implementing agencies to divert water from the Mahaweli River to water-scarce areas in and around the North Central Province (NCP). Upon completion of the proposed investments, the available supply of water is expected to increase by over 1,200 million cubic meters (MCM) per year.[8] The increase in available water will be allocated to hydropower, DMI uses and agriculture. The following quantifiable economic benefits were considered:

(i) **Economic benefits from increased agricultural production.** The increase of irrigation water is expected to result in crop yield increases within existing cultivation areas and in increased cultivated areas.

(ii) **Economic benefits from increased provision of raw water for domestic, municipal and industrial uses.** These consist of economic benefits from improved sources of non-piped drinking water (which mainly consists of avoided health costs and reductions in the cost of obtaining water), and the benefits of improved sources of piped drinking water. The latter benefits are derived from reductions in the cost of supplying water and the acceleration of piped water coverage vis-à-vis the "without project" scenario.

(iii) **Economic benefits from increased hydropower generation.** Until the completion Phase 1, the project will provide a modest increase in the country's hydropower generation. The economic benefits of the expected increase are partly

[8] *Water Balance Study of NCP Canal Project* (MCB, 2012). This section heavily relies on this study, which is hereinafter also referred to as "the Water Balance Study".

offset upon completion of the NCP Canal in 2029, after which overall hydropower generation will then be slightly lower than without the project.

In addition to the quantifiable benefits from increases in agricultural production, DMI water, hydropower generation, the following benefits were assessed qualitatively: increased food self-sufficiency, and increased internal security.

1. Economic Benefits from Increased Agricultural Production

15. **Overview.** The primary economic benefit of NCPCP is increased agricultural production through improved deliveries of irrigation water. More specifically, improved irrigation water supply is expected to result in:

(i) an increase in the cropping intensity (CI) on existing cultivated areas (the cropping intensity is the fraction of the cultivated area that is harvested),

(ii) an increase in paddy yields owing to secured supply of water, and

(iii) an increase in the production of high-value crops (such as fruit and vegetables); this effect is not only expected because high-value crops require a reliable supply of irrigation water, but also because farmers tend to fulfill their own paddy needs first before growing other food crops

In addition, the project will invest in an institutional support program to help the implementing agencies better manage their existing irrigation infrastructure. These investments are also expected to result in increases in water productivity, which would result either in increases in cropping intensity or maintain the same level of cropping intensity using less water.

16. **Structure of the analysis.** The economic analysis of benefits from increased agricultural production proceeds as follows:

(i) **Step 1: Estimate agricultural production without project.** In the absence of the project, yields are expected to decrease as a result of climate change.

(ii) **Step 2: Estimate increases in cropping intensities.** The project is expected to increase yields in areas that are currently cultivated and irrigate areas that are currently not cultivated. Both types of increases were measured by estimating increases in cropping intensities. The result of the first step is an estimate of the increase in the total harvested area compared to the “without project” scenario.

(iii) **Step 3: Estimate changes in cropping patterns.** The project would enable farmers to increase the production of crops with a higher value added than paddy. The result of this step is the definition of a realistic crop mix in the benefit area.

(iv) **Step 4: Estimate economic surplus.** The consumer and producer surplus was estimated for each crop in the selected mix, and converted to net economic benefits by crop, expressed in mid-2014 rupees.

17. **Step 1: Estimate agricultural production without project.** The project will improve irrigation in an area of about 232,500 hectares of irrigable land in Sri Lanka’s dry zone (“the Agricultural Benefit Area”). About 214,500 hectares is currently already used to grow crops, mostly paddy, and the remaining 18,000 hectares will be cultivated upon completion of Phase 1. According to a recent analysis, air temperatures in the project area will be 1.3ºC to 1.7ºC higher

in 2050 than during 1961-1990.[9] Lobell et al. estimate that paddy yields in South Asia will, on average, decrease by 4.0 percent per 1ºC temperature increase.[10] These parameters were used to estimate the decrease in agricultural production in the "without project" (WOP) scenario. It was assumed that agricultural production would not decrease because of climate change in the "with project" (WP) scenario as the newly built irrigation infrastructure would be able to absorb adverse changes in the availability of water for agriculture.

18. **Step 2: Estimate increases in cropping intensities.** At present, cropping intensities in existing cultivated areas in the Agricultural Benefit Area are suppressed, mainly because of persistent shortages of irrigation water (see Annex 1 for an overview of the relationship between irrigation and paddy yields in the dry zone). Records of the Mahaweli Authority of Sri Lanka (MASL) indicate that cropping intensities are about 50% lower in Yala (the dry season, which usually lasts from May to August) than in Maha (the wet season, which starts in September ends in March of the following year). To assess the potential impact of NCPCP on agricultural production, the Agricultural Benefit Area was divided in 27 smaller homogeneous areas. For each of these sub-areas, MMDE identified current cropping intensities (CIs) based on MASL records and prepared forecasts of cropping intensities that would be realized upon completion of the required irrigation infrastructure. The weighted average CI of the entire Agricultural Benefit Area is projected to increase by about 31%, from 1.42 now to 1.86 upon completion of Phase 2. (An econometric analysis for paddy production in the whole of Sri Lanka showed that moving from rain-fed to irrigated water supply would increase average paddy yields by at least 30%; see Annex 3). For obvious reasons, projected increases are higher for areas where irrigation is poor or mediocre than in areas that are already well-irrigated (see Table 5 for a summary; refer to Annex 2 for assumptions by sub-area.) The assumed increases are deemed conservative: MMDE assumes that CIs in well-irrigated areas will increase by about 3%, from 1.87 to 1.93; and, upon completion of NCPCP, when the entire Agricultural Benefit Area will receive adequate supplies of irrigation water in both seasons, CIs in areas that are currently not well irrigated are assumed to increase to 1.80, which is 4% lower than CIs that are already achieved now in areas with good irrigation (1.87).

Table 5: Current and Projected Cropping Intensities in the Agricultural Benefit Area

Type of area	Current Cropping Intensity			Projected Cropping Intensity*		
	Maha	**Yala**	**Total**	**Maha**	**Yala**	**Total**
Currently cultivated						
- Good irrigation (CI>1.5)	1.00	0.87	1.87	1.00	0.93	1.93
- Medium irrigation (CI 1.0-1.5)	0.76	0.47	1.23	1.00	0.80	1.80
- Poor irrigation (CI ≤1.0)	0.79	0.02	0.81	1.00	0.80	1.80
Currently idle land	-	-	-	0.63**	0.89	1.52
ALL AREAS	**0.86**	**0.57**	**1.42**	**0.97**	**0.89**	**1.86**

Source: ADB, based on MASL (current cropping intensities) and MMDE (projected cropping intensities)
* In first year after completion of relevant irrigation infrastructure
** CI < 1.00 because part of the currently idle land will be allocated to sugar cane, where harvests are assumed to take place during Yala only

19. It is important to note that cropping intensities projected by MMDE were based on the assumption that improved deliveries of irrigation water will be used exclusively to grow more

[9] C. S. De Silva. *Impact of Climate Change on Water Resources and Agriculture in Sri Lanka*. Proceedings of the International Conference on Climate Change Impacts and Adaptations (2013).
[10] D.B. Lobell et al. *Prioritizing Climate Change Adaptation Needs for Food Security in 2030* (Science, Feb 2008).

paddy, both in Maha and Yala ("paddy/paddy", in MCB parlance). This assumption was made to ensure that sufficient irrigation water would be available for increased agricultural production, irrespective of the selected crop mix. Because paddy requires more water per hectare than other food crops (OFCs), any combination of paddy and OFCs will require less water than growing paddy only. Because part of the irrigation water will be used for OFC production, the Water Balance Study contains conservative projections of water available for productive uses.

20. **Step 3: Estimate changes in cropping patterns.** At present, MASL manages a series of major irrigation schemes that are located in or near the Agricultural Benefit Area, and which already enjoy an adequate supply of irrigation water, notably System B, C and H. Actual cropping patterns in these systems were analyzed to define cropping patterns in newly harvested areas in the benefit area.[11] Based on the analysis, the following allocation rules were formulated (an exception to the rules is noted below):

(i) **Maha: 100% paddy.** It is unusual for farmers in the Agricultural Benefit Area to grow crops other than paddy in Maha, even in well-irrigated areas. For this reason, it was assumed that the entire increase in the harvested area in Maha would be allocated to paddy.

(ii) **Yala, major systems: 75% paddy, 25% OFCs.** In well-irrigated systems in the dry zone Sri Lanka, 10 to 40% of the harvested area is allocated to OFCs in Yala. For the purpose of this analysis, it assumed that 25% of the increase in the harvested area in Yala would be allocated to OFCs.

(iii) **Yala, minor systems: 25% paddy, 75% OFCs.** Farmers tend to use a substantially higher proportion of cultivated land for OFCs in minor systems than in major systems. For this reason, it was assumed that 75% of the increase in the harvested area in such systems would be allocated to OFCs in Yala, and the remainder to paddy (three of the 27 sub-areas were classified as such, and had a combined area of about 39,000 hectares or about 16% of the total Agricultural Benefit Area).

There is one exception to the above rules. The Water Balance Study assumed that about 6,600 hectares in the Kantale area (which are currently fallow) will be allocated to sugarcane to help reduce Sri Lanka's considerable sugar imports. This assumption was also used in this economic analysis. The Kantale area is therefore the only area where a single type of agricultural produce will be harvested throughout the year (in all other areas, there will be a mix of paddy and OFCs).

21. The pre-feasibility study prepared by MCB for MMDE contains expected cropping patterns for the "with-project" scenario.[12] These patterns are broadly comparable to current cropping patterns in Systems B, C and H (as mentioned before, these are well-irrigated areas in or adjacent to the Agricultural Benefit Area, and were therefore seen as representative of irrigation systems to be developed by the project). The study anticipates that about half of the increase in the harvested area for OFCs will be used for banana and maize (24% each), and the remainder for vegetables (14%), green gram (14%), dry chillies (11%), ground nut (11%) and big onions (2%). These assumptions were adopted for the analysis.

22. Upon completion of all irrigation infrastructure in 2030, and taking into account the impacts of climate change, the harvested area will be approximately 107,000 hectares larger,

[11] For details, see Attachment 4 to Volume I of *Preparatory Survey for Moragahakanda Development Project – Final Report* (JICA, 2009).

[12] *Economic Analysis in Financial and Economic Terms of the North Central Province Canal Project of Mahaweli Development Program* (MCB, 2012).

and annual agricultural production over 1.2 million tons higher vis-à-vis the "without-project" scenario (Table 6). About 63% of the expected increase in the harvested area will be absorbed by paddy, 6% is allocated to sugarcane and the remaining 31% to OFCs.

Table 6: Harvested Area and Agricultural Production, 2030

Crop	Harvested Area ('000 hectares)			Agricultural Production ('000 tons)		
	WOP	WP	∆Area	WOP	WP	∆Production
Paddy, Maha	196	226	30	1,162	1,328	167
Paddy, Yala	96	135	38	493	687	194
OFCs	33	66	33	231	462	231
Sugarcane	-	7	7	-	643	643
TOTAL*	**325**	**433**	**107**	**1,885**	**3,120**	**1,234**

Source: ADB (assumed allocation), MASL (other)

23. **Step 4: Estimate economic surplus.** An economic surplus model was used to measure project benefits from increased agricultural production. As a result of the project intervention, changes in the quantity of a commodity (in this case paddy, OFCs and sugarcane) will result in product price changes, and the combined effects of these changes will result in changes to economic welfare, also called "economic surplus". Economic surplus consists of two elements: (i) consumer surplus, and (ii) producer surplus. Consumer surplus is defined as the extra amount a consumer would have been prepared to pay, and is measured as the area below the demand curve and above the price line. The basic premise of consumer surplus is that at a certain market price there are some consumers who would be willing to pay a higher price to obtain the same quantity, and their welfare is increased by obtaining the product at a lower price. The traditional measure of producers' surplus is the area above the product supply curve and below the price line. This area represents the difference between what a producer actually receives for a sale and the minimum amount s/he would have been prepared to accept.

24. The economic surplus model identified consumer and producer effects both within the Agricultural Benefit Area and in the rest of Sri Lanka. In the Agricultural Benefit Area, there will be a direct effect on producers through the increase in supply of a commodity. Assuming competitive conditions prevail, this will also have broader implications on the rest of the country through the reduced market price as a result of increased supply. This will impact upon consumers (who gain) and producers (who lose) from reduced market prices.

25. The economic value of final outputs and agricultural inputs was estimated by converting financial prices into mid-2014 economic prices using conversion factors mentioned in para 9. Paddy yields were assumed to increase by 0.1 ton/ha per year in Maha until the end of Phase I and remain stable thereafter. Assumed paddy yields in Yala and OFC yields were actual yields realized in System B, C and H during 2008-2011/12. The present value of the economic benefits from increased agricultural production is estimated at SLRs 104.9 billion (Table 7), or about 90% of the total present value of the project's quantifiable benefits. This was comprised of SLRs 41.3 billion from paddy, SLRs 24.0 billion from sugarcane, and SLRs 39.5 from OFC. In terms of the welfare effects consumers in the project area gained SLRs 40.9 billion and in the rest of the country by SLRs 74.6 billion, while producers in the project area gained SLRs 61.4 billion, but in the rest of country lost SLRs 72.0 billion, due to lower market prices.

Table 7: Results of Discounted Economic Surplus Analysis
(SLRs billion)

	Paddy	Sugarcane	OFC	Total
Project area				
Consumer surplus	15.1	10.0	15.8	40.9
Producer surplus	25.7	13.5	22.3	61.4
Total surplus	40.8	23.4	38.0	102.3
Rest of country				
Consumer surplus	25.5	5.7	43.5	74.6
Producer surplus	-25.0	-5.1	-42.0	-72.0
Total surplus	0.6	0.6	1.5	2.6
Total				
Consumer surplus	40.6	15.6	59.2	115.5
Producer surplus	0.7	8.4	-19.7	-10.6
Total surplus	41.3	24.0	39.5	104.9

Source: ADB estimates.

2. Economic Benefits from Increased Provision of Raw Water for DMI Uses

26. **Overview.** An important secondary economic benefit of the NCPCP project is improved provision of raw water for domestic, municipal and industrial (DMI) uses. The Water Balance Study envisages that, by 2030, the project will provide 162 million cubic meters (MCM) of raw water per year to the districts of Anuradhapura, Matala, Polonnaruwa, Vavuniya and Trincomalee ("the DMI Benefit Area"), which will be used to provide piped water to about 830,000 persons.[13] In that year, the number of beneficiaries will account for approximately 33% of the total population of the DMI Benefit Area.[14] It is important to note that this amount is the planned allocation of raw water from infrastructure constructed by the NCPCP to the National Water and Sewerage Development Board (NWSDB). The project will not invest in water treatment plants or infrastructure needed to convey water from treatment facilities to final users; this would be the responsibility of the NWSDB, local authorities and other organizations.

27. **Principal sources of drinking water in the DMI Benefit Area.** In 2012, the total population of the DMI Benefit Area was about 2.3 million, or 11% of the national total. About 26% of households in the area had access to piped water, which was lower than the national average of 31%. Most other households relied on private well or communal facilities (such as stand pipes and tube wells) as their principal source of drinking water (Table 8). Increased provision of raw water is expected to lower the economic cost of non-piped water sources (as non-piped water will be more easily accessible and of better quality than is presently the case), and accelerate the increase in piped water coverage.

[13] By 2030, Phase 1 and 2 of the NCPCP will provide an estimated 162MCM of drinking water per year. NWSDB estimates that 70MCM would be required for 358,000 persons in selected parts of the DMI Benefit Area. The total number of beneficiaries was therefore estimated at (358,000 x 162/70 =) about 830,000.

[14] Assuming an average annual growth rate of 0.5% (see footnote 21 for details).

Table 8: Principal Source of Drinking Water in DMI Benefit Area, 2012
(percentage)

District	Piped Water	Private Well	Communal Facilities*	River or Lake	Other Sources
Anuradhapura	24	54	18	2	2
Pollanaruwa	22	57	19	2	0
Vavuniya	8	71	18	0	3
Trincomalee	36	54	3	2	5
Matale	29	43	23	6	0
All Districts	**26**	**53**	**17**	**3**	**2**

Source: Sri Lanka Statistics Bureau (2014)
* Stand pipes, tube wells and similar facilities

28. **Typology of economic benefits from increased provision of raw water.** The economic benefits of the NCPCP with respect to raw water consist of:

(i) **Economic benefits from improved sources of non-piped drinking water supply.** The NCPCP's planned major storage and conveyance infrastructure will provide more (and more reliable) supplies of raw water to areas that are currently water-scarce. This will provide substantial benefits to persons living in the DMI Benefit Area, also to those without access to piped water, mainly by lowering the cost of obtaining water for domestic uses (easier access to water sources, lower storage costs) and by lowering health costs (better quality water, more reliable supply of water). This is especially relevant given the very high incidence of chronic kidney disease (CKD) in the DMI Benefit Area, which is widely believed to be associated with the absence of safe drinking water supply.[15]

(ii) **Economic benefits from improved sources of piped drinking water supply.** The project will enable the NWSDB to provide piped water at a lower cost than without the project, mainly because of substantial cost savings on transmission mains, source works and groundwater development. In addition, because the project already provides raw water, this would not only lower the cost of providing water, but would presumably enable the Board to achieve its coverage targets for the project area earlier than would otherwise be the case. This would provide economic benefits of piped water (which are higher than the economic benefits of non-piped water) to a sizable number of beneficiaries in the DMI Benefit Area at an earlier stage than without the project.

29. **Economic benefits from improved sources of non-piped drinking water supply.** Upon completion of the infrastructure in 2030, about 200,000 persons who currently do not have access to piped water will have improved access to raw water that they can collect, treat and store or consume. This benefit is, however, only likely to accrue in Yala (when water tends to be scarce) and to persons living near the newly constructed canals. Upon completion of the Upper Elahera Canal in 2023, this "area of influence" will mainly consist of the southern part of the Anuradhapura District. Once the NCPCP is completed in 2029, the area of influence will also contain the central and northern parts of the Anuradhapura District and most of the Vavuniya District. In 2012, these areas had a combined population of approximately 550,000, or 24% of

[15] See for example *Investigation and Evaluation of Chronic Kidney Disease of Uncertain Aetiology in Sri Lanka – Final Report* (WHO, 2012).

the total population of the DMI Benefit Area. Of these, 18% had access to piped water and the remainder relied on non-piped sources. The most important economic benefit from improved source of non-piped drinking water supply is a reduction in the CKD mortality rate. In addition, the project will provide time savings and other health benefits.

30. At present, about 100,000 persons in Sri Lanka are affected by chronic kidney disease. The disease is heavily concentrated in the DMI Benefit Area, where mortality rates have rapidly increased in recent years. Although the specific causes of CKD are unknown, the CKD is most prevalent in areas with heavily polluted water sources (which are often areas with high fertilizer use). Because many CKD deaths are not recorded, there is considerable uncertainty about the CKD mortality rate. Estimates range from several hundred per year in the dry zone to 5,000 persons in the North Central Province alone. For the purpose of this analysis, a conservative estimate of 500 was used for the area of influence. Most casualties are middle-aged farmers, who work with water that is polluted by fertilizer and pesticides and tend to live in areas without access to adequate medical facilities or water supply systems. There is consensus within the government and health community that the provision of clean water to the affected areas would significantly reduce the CKD mortality rate, and it was assumed that the project would reduce the CKD mortality rate by 50 percent.[16] The estimated value of avoided loss of life due to CKD was used to estimate economic benefits from the improved provision of raw water by the project. The value of the avoided loss of life was estimated as the present value of 20 years of productive years lost.[17] The avoided loss attributed to the project was only computed for persons in the area influence without access to piped water.

31. In recent years, ADB has financed a series of rural water supply projects in areas in or adjacent to the DMI Benefit Area, of which the Small Towns and Rural Arid Areas Water Supply and Sanitation Project and the Dry Zone Urban Water and Sanitation Project (original loan and additional financing) are the most relevant.[18] For the preparation of these projects, surveys were undertaken to assess the economic cost of non-piped water. The results of the surveys were used as the basis for assessing the avoided costs (i.e. the economic benefits) of moving from the current unreliable source of non-piped water to: (i) an improved source of non-piped water, and (ii) a piped water connection. The avoided costs considered here consist of: (i) resource cost savings (the avoided costs of collecting, treating and storing non-piped water), and (ii) time saved from not having to collect water which could translate into productivity gains for those engaged in income-generating activities.[19]

32. Table 9 shows parameters that were used for quantifying the economic benefits of the above-mentioned projects when moving from a non-piped source to a piped source. Economic benefits were conservatively estimated by assuming that the lowest values for resource cost savings (SLRs 150/m^3); because of data limitations, health benefits were not quantified. The economic value of time savings of collecting water was adjusted downward to reflect lower incomes and higher unemployment rates in peri-urban and rural areas (where most of the benefits will be realized) than in urban areas (where the surveys had been taken). Assuming an

---

[16] Myles F. Elledge et. al. *Chronic Kidney Disease of Unknown Etiology in Sri Lanka: Quest for Understanding and Global Implications*. RTI Research Brief, May 2014.

[17] G. Hutton. *Global Costs and Benefits of Drinking Water Supply and Sanitation Interventions to Reach the MDG Target and Universal Coverage* (WHO, 2012).

[18] Dry Zone Urban Water and Sanitation Project – Additional Financing (RRP SRI 37381) and Small Towns and Rural Arid Areas Water Supply and Sanitation (RRP SRI 37381).

[19] The value of incremental water was not included, because the difference between willingness-to-pay levels and the financial cost of piped water (which ADB normally uses to estimate this value) is low in Sri Lanka, especially in peri-urban and rural areas.

average household size of 4 and consumption of non-piped water of 80 liters per capita per day, the time cost savings were estimated at SLRs 79/m^3.[20] The total savings, including the resource cost saved, was thus estimated at (150+79=) SLRs 229/m^3, which is equivalent to SLRs 251/m^3 in mid-2014 prices. This amount, however, is the reduction in economic costs when moving from a non-piped to a piped water source. In the area of influence, the reduction in economic costs when moving from an existing non-piped water source to an improved non-piped water source will mainly consist of time savings (as water will be better accessible upon completion). There are no benefits expected from reductions in the resource cost, because this cost mainly consists of treatment and storage, which will need to be undertaken both in the "with project" and "without project" scenario. Because the benefits will only be realized in Yala, they were estimated for half the annual volume of non-piped water consumed by persons living in the area of influence. The present value of the quantifiable benefits from improved sources of non-piped drinking water supply (including health benefits from reduced CKD mortality) is estimated at SLRs 4.8 billion, or about 4.1% of the total present value of the project's benefits.

Table 9: Parameters Used For Quantifying Economic Benefits of Water Supply

Town	**Resource Cost Saved** (SLRs/m3)*	**Time Savings** (SLRs/HH/day)*
Mannar	181	59
Chilaw	151	85
Puttalam	161	103
Vavuniya	150	157
Assumption Used	**150**	**25**

Source: ADB (2012, 2014)
* 2012 economic prices

33. **Economic benefits from improved sources of piped drinking water supply.** In November 2012, ADB and the government signed a loan agreement for additional financing for the Dry Zone Urban Water and Sanitation Project.[21] Most of the loan proceeds will be allocated to finance piped water supply systems in three towns located in or near the DMI Benefit Area; the loan document also contained information on costs of the systems of Muttur and Polonnaruwa, which are both located inside the benefit area. The average per capita investment cost of the five systems was approximately $600 expressed in 2012 financial prices including taxes (Table 10); about 30% or $184 per capita consisted of the cost of primary transmission mains, source works and groundwater development. This amount was converted into economic prices to obtain an estimate of cost savings for providing raw water induced by the project.

34. The government's "Mahinda Chintana Vision for the Future 2010" envisages that 60% of the nation's households will have access to piped water supply by the end of 2020, up from 31% in 2012.[22] This is an ambitious target, given that access to piped water has increased, on average, by about 1% per year since 2000.[23] It is assumed that, in the "without project" scenario, coverage of piped water service in the DMI project area will continue to increase by

[20] This average value time savings per cubic meter of water was computed as: SLR 25 / (4 x 0.08m^3) = 79. The rural time saving was based on unskilled labor wage rate of SLRs 420 per day, assuming that one hour per day was spent on collecting water for one household, and that 50% of water was collected by a person in the labor force.

[21] *Proposed Loan for Additional Financing Democratic Socialist Republic of Sri Lanka: Dry Zone Urban Water and Sanitation Project.* Report and Recommendation of the President to the Board of Directors. ADB. Nov 2012.

[22] Quoted in *NWSDB Corporate Plan 2012-2016*, Ministry of Water Supply and Drainage (2011).

[23] According to UNICEF and WHO, the proportion of Sri Lanka's population with piped water on premises was 21% in 2000 and 29% in 2010 (*Progress on Drinking Water and Sanitation – 2012 Update*).

this historical growth rate, from 26% in 2012 to 74% in 2060. Assuming that NWSDB and local authorities wish to maximize the benefits from the increase in raw water to be provided by the project, the "with-project" scenario assumes that the increase in coverage will be higher than 1% per year in two periods: upon completion of Phase 1 (2024) and Phase 2 (2029) of the project. More specifically, it was assumed that the number of persons with access to piped water will increase:

(i) by 358,000 in the five-year period following the completion of the UEC (2025-2029),

(ii) by 471,000 in the five-year period following the completion of the NCPCP (2030-2034), and

(iii) by 0.5% during per year during 2035-2057; from 2049 onward, the number of persons with access to piped water will be the same as in the "without project" scenario (this means that project-financed infrastructure will achieve intermediate targets earlier, but there is no difference in coverage at the end of the project implementation period)[24]

Table 10: Construction Cost of Selected Piped Water Supply Systems
(2012 prices including taxes and duties)

Town	**Plant Capacity** (m^3/day)	**Persons Served** ('000)*	**Subproject Cost** ($ million)	**Average Cost** ($/person)
Pollanaruwa	13,500	81	56.1	693
Muttur	8,500	51	30.9	606
Chilaw	9,000	54	31.0	574
Puttalam	9,000	54	38.8	718
Vavuniya	12,000	72	32.8	455
Total	**52,000**	**312**	**189.6**	**608**

Source: ADB (2012, 2014)
* Based on following assumptions: 100% of plant capacity used, losses account for 20% of water production, 90% of water production after losses is consumed for domestic purposes, average consumption is 120 l per capita per day.

35. As a result of the acceleration of the connection program, the economic benefits of piped water will accrue to several hundreds of thousands of beneficiaries in an earlier stage than without the project (Figure 1). The net economic benefits of the acceleration were estimated based on the following assumptions:

(i) Incremental economic benefits of piped water consists of resource cost savings and time savings for collecting water; as described in para 37, these benefits were estimated at SLRs 229/m^3 of water formerly taken from non-piped sources.

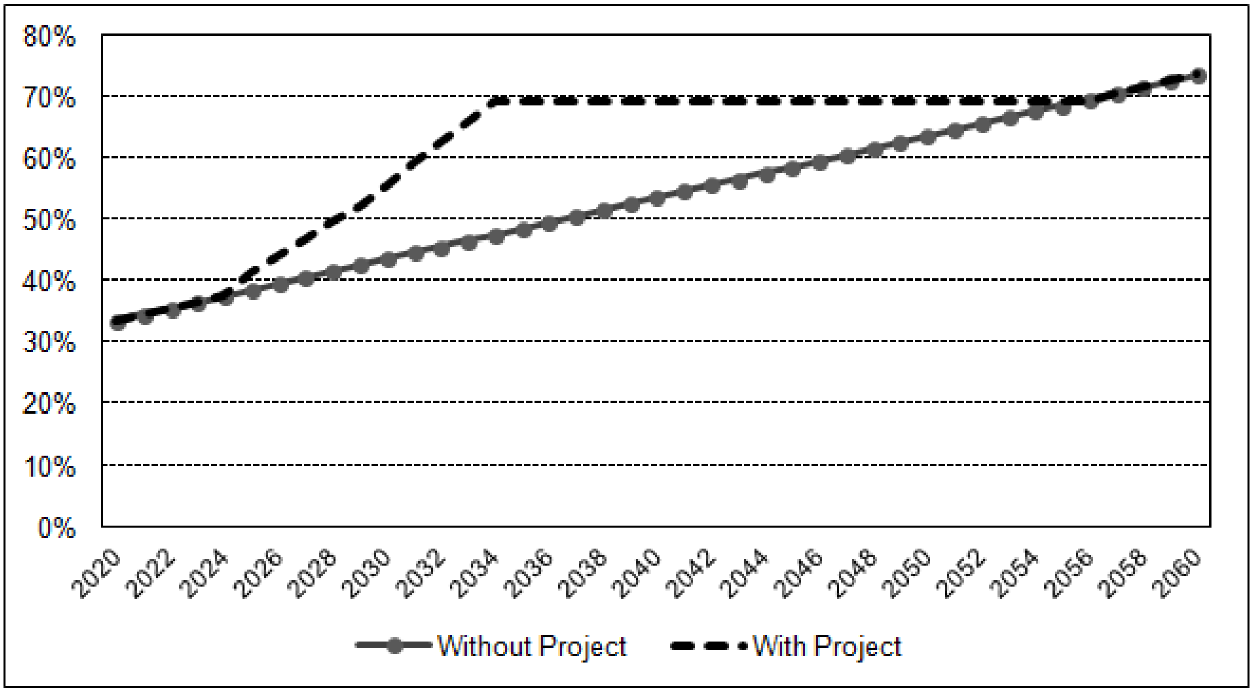
(ii) Incremental economic costs consist of the economic investment cost (which was valued at $527 per capita for system costs plus $50 for house connections), and the incremental O&M cost, which was estimated at 25% of the investment cost.[25] Because of the cost savings mentioned in para 38, the per capita investment cost will be 30% lower in the "with-project" case than in the "without-project" scenario.

[24] Both scenarios assume that the population in the DMI Benefit Area will continue to increase by 0.5% per year, which is lower than the annual growth rates during 1981-2001 (1.3%) and 2001-2012 (1.1%). The figures of 358,000 and 471,000 were based on NWSDB estimates (see also paragraph 25).

[25] $651 is the per capita economic cost of systems improvement expressed in mid-2014 prices. It is equivalent to the financial cost of $608 in 2012 prices including taxes.

36. The present value of the acceleration of piped water coverage is estimated at SLRs 4.8 billion, or approximately 4.2% of the total present value of the project's benefits. Note that this is a conservative estimate, because the analysis does not include the net economic benefits of piped water accruing to non-residential piped water users.

Figure 1: Coverage Rates of Piped Water Supply in DMI Benefit Area, 2020-2060
(percent population with access to piped water)



Source: ADB estimates.

3. Economic Benefits from Increased Hydropower Generation

37. **Overview.** In 2012, hydropower plants in Sri Lanka generated approximately 3,290 GWh of electricity, or 28% of the country's total power generation in that year (Table 11). Because most of Sri Lanka's hydropower potential has been used, and because demand for electricity is rapidly increasing, the share of hydropower has steadily declined in recent years. To meet increased demand for electricity, the country increasingly relies on thermal power, most of which is generated by independent power producers (IPPs) and purchased by the Ceylon Electricity Board (CEB), which has a statutory monopoly on electricity distribution.

Table 11: Electricity Generation by Source, 2008-2012
(GWh '000)

Source	2008	2009	2010	2011	2012
Thermal	5.76	5.98	5.00	6.79	8.34
Hydropower	4.13	3.88	5.63	4.62	3.29
Other renewables	0.01	0.03	0.09	0.12	0.17
Total	**9.90**	**9.88**	**10.72**	**11.53**	**11.80**
Hydropower as % of total	42	39	53	40	28

Source: Central Bank of Sri Lanka (2014)

38. **Incremental hydropower generation.** At present, there are nine large-scale hydropower plants operating in the Mahaweli Complex. Upon completion of the raising of Minipe Anicut in mid-2018, two of these plants (Bowatenna and Moragahakanda) will together generate an additional 18GWh per year until 2030, when the second phase of the NCPCP will be completed. With the opening of the NCPCP, annual hydropower generation will be 42GWh lower than in the "without-project" scenario. The amounts of 18GWh and 42GWh are equivalent to 0.5% and 1.3% of the country's total hydropower generation in 2012, respectively.

39. **Valuation of incremental hydropower generation.** Initially, the project will result in an increase in hydropower generation of 18GWh per year. As a result, CEB will not need to purchase this amount from IPPs, which would otherwise be relied on to meet increases in demand for electricity. In 2012, the average cost of a kWh of electricity generated by an IPP was SLRs 21.79.[26] Excluding taxes, this was equivalent to SLRs 21.23 (or $0.16) in mid-2014 prices. This amount was used as a conservative estimate of the economic benefit of generating one kWh of hydropower (the estimate is conservative because the cost of thermal power generated by IPPs does not fully reflect environmental costs).[27] From mid-2018 to 2029, the economic benefit of incremental hydropower generation was therefore estimated at (18 x 1,000,000 x 21.23 =) about SLRs 382 million ($2.9m) per year. From 2030 until the end of the project's assumed economic lifetime in 2060, the economic benefit is minus SLRs 892 million per year. Even though the hydropower losses in 2030 and after are, in absolute terms, greater than the hydropower gains during 2018-2029, the net present value of the hydropower generation is nonetheless positive over the economic lifetime of the project. This is because the gains are realized earlier than the losses. At a discount rate of 12% (the assumed economic opportunity cost of capital), the net present value of the incremental hydropower generation is about SLRs 0.2 billion, or approximately 0.2% of the total present value of the project's benefits.

4. Other Economic Benefits (Not Quantified)

40. **Increased food security.** The economy of the Agricultural Benefit Area is heavily dependent on irrigated agriculture, and droughts therefore adversely affect food security in the area. According to a recent survey undertaken by the World Food Programme, the 2014 Maha drought doubled food insecurity in 15 of Sri Lanka's 26 districts (including all four districts in the Agricultural Benefit Area) and increased the share of households with inadequate diets of 6-18%.[28] The NCPCP would improve food security in the Agricultural Benefit Area and thereby potentially protect at least 70,000 households from malnutrition during a drought event.

41. **Increased internal security.** The NCPCP is the capstone of the Mahaweli Development Program (MDP), which was formulated in 1968 with the objective of harnessing the hydropower and irrigation potential of the Mahaweli River. The Civil War that ravaged Sri Lanka from the early 1980s until 2009 caused a major delay in the implementation of MDP, and impoverished most of the area that stands to benefit from NCPCP. This observation especially applies to the districts of Anuradhapura and Vavuniya, which were located in the front line of the conflict, and where most of the project's beneficiaries are living. This means that the project will also serve the higher-level goals of restoring prosperity in a formerly conflict-affected area and help prevent the resumption of civil strife in that area.

---

[26] *Generation Performance in Sri Lanka (2012, First Half)*. Public Utilities Commission of Sri Lanka.

[27] Because the hydropower plants in the Mahaweli complex do not need to be modified to increase generation, the economic cost of producing an incremental unit of hydropower was assumed zero.

[28] *Sri Lanka - Rapid Drought Impact Assessment: Food Security and Livelihoods Affected by Erratic Weather*. World Food Programme. April 2014.

IV. RESULTS

42. **Assessment of economic feasibility.** The ENPV (discounted at 12%) of the project is estimated at SLRs 11.7 billion ($89.5 million). This means that NCPCP is considered economically feasible. The same conclusion can be derived from the project's EIRR which is estimated at 13.1%, higher than the minimum required rate of 12%. The project is also expected to generate significant non-quantifiable benefits, especially by accelerating the socio-economic development of an area that was adversely affected by internal conflict during most of the past three decades.

43. **Composition of economic benefits.** As expected, increased agricultural production is the most important source of quantifiable economic benefits, accounting for over 90% of total benefits (Table 12). Benefits from cost savings on raw water provision and the accelerated development of piped water account for most of the remainder. Economic benefits from incremental hydropower generation were not significant.

Table 12: Composition of Quantifiable Economic Benefits of NCPCP

Economic Benefit	Present Value of Benefits	
	SLRs billion	**% Total**
1. Increased agricultural production	104.9	91.0
2. Increased raw water provision	10.1	8.8
3. Increased hydropower generation	0.2	0.2
Total	**115.3**	**100.0**

Source: ADB estimates.

44. **Sensitivity analysis.** Sensitivity tests were conducted by varying the project's investment cost, O&M cost and benefits (Table 13). The results of the tests indicate that the economic feasibility of NCPCP is sensitive to unfavorable changes to the investment cost and economic benefits. If the investment cost is 11.5% higher, or benefits are 11.2% lower) than in the base case, the EIRR will fall below 12%. The project's EIRR is relatively insensitive to changes in the O&M cost.

Table 13: Sensitivity of Project EIRR to Changes in Selected Variables [a]

	Change to Base case	**ENPV [b]** (SLR billion)	**EIRR** (percent)	**Switching Value** (percent)
Base case	**-**	**11.7**	**13.1**	**-**
Investment cost	+10%	1.6	12.1	+11.5
O&M cost	+10%	10.7	13.0	+124.9
Benefits	-10%	1.2	12.1	-11.2

Source: ADB estimates.
[a] ENPV: economic net present value, EIRR: economic internal rate of return.
[b] Computed based on assumed economic opportunity cost of capital of 12%.

V. DISTRIBUTION AND POVERTY ANALYSIS

45. **Distribution of project benefits to stakeholder groups.** To quantify the distribution of project benefits by stakeholder group, it is necessary to allocate the present value of the economic benefits and economic costs to each group. The difference is the net gain (or loss) of the project to that stakeholder group. Three stakeholder groups were considered: government, agricultural producers and water consumers. Their gains and losses can be summarized as follows (Table 14):

(i) **Government.** The government will finance the investment and O&M cost of the project. Because the project will not generate incremental revenue (with the exception of a small increase in revenue from hydropower), this stakeholder incurs a substantial net loss.

(ii) **Producers.** The project is expected to generate a substantial producer surplus in the Agricultural Benefit Area, mainly because it will increase in the harvested area through better provision of irrigation water and mitigate adverse impacts of climate changes. However, these gains are offset by losses to producers in the rest of Sri Lanka, who will receive lower prices for their produce as a result of the supply shift.

(iii) **Consumers.** The increase in agricultural production is expected to result in lower output prices than in the “without project” scenario, which would benefit consumers in both in the Agricultural Benefit Area and the rest of the country. In addition, the project will also improve the provision of raw water to the benefit area. This will benefit consumers of non-piped water, in the form of health benefits and time saved for the collection and storage of water. It will also benefit consumers of piped water, many of whom will gain access to a piped water connection at an earlier stage than compared to a “without-project” scenario.

46. The poverty impact ratio (PIR) was estimated, assuming a national poverty rate of 6.9%, a rural poverty rate of 7.6%, and a poverty rate of small farmers of 40%. Because the net gains from agricultural producers accounted for most of the project’s gains, the PIR is closely related to the poverty rate of small farmers. As shown in Table 14, the ratio was estimated at 31%.

Table 14: Distribution of Project Benefits
(SLRs billion)

Present Value of:	**Govern-ment**	**Consumers**		**Producers**		**TOTAL**
		Project area	Rest of SL	Project area	Rest of SL	
Economic benefits						
- Agricultural	-	40.9	74.6	61.4	-72.0	104.9
- Piped water	1.6	3.2	-	-	-	4.8
- Non-piped water	-	5.3	-	-	-	5.3
- Hydropower	0.2	-	-	-	-	0.2
Economic costs	-103.6	-	-	-	-	-103.6
GAINS AND LOSSES	**-101.7**	**49.4**	**74.6**	**61.4**	**-72.0**	**11.7**
Benefits to poor	-6.9	18.7	5.0	24.6	-5.5	35.8
Poverty Impact Ratio						**31.1%**

Sources: ADB estimates, WB (2013), IFAD (2014).
* Assumed poverty rates: national 6.9%, rural 7.6%, small farmers 40%.

ANNEX 1
RELATIONSHIP BETWEEN IRRIGATION AND PADDY YIELDS

A1.1 Paddy yields were analyzed for all districts located in the dry zone of Sri Lanka, where climatic conditions are similar to those in the Agricultural Benefit Area. During 2006-2012, the average yield per net hectare (i.e. the harvested area, as opposed to the cultivated area) ranged from 3.34 tons in rainfed areas in Yala to 4.80 tons in areas served by major irrigation schemes in Maha (Table A1.1). For each type of irrigation major scheme, minor scheme or no irrigation average yields were higher in Maha than in Yala, albeit by a small margin (less than 10% in most years). In contrast, the type of irrigation made a major difference to yields in all years. In both seasons, yields in major schemes were about 45% higher than in rainfed areas; yields in minor schemes were about 20% higher. A more rigorous econometric analysis, which was based on a more extensive dataset, suggests that moving from a rainfed area to an irrigated area results in even higher yield differentials (see Annex 3 for details).

Table A1.1: Paddy Yields in the Dry Zone of Sri Lanka, 2006-2012
(ton per net hectare)

Year		Maha			Yala	
	Major Schemes	Minor Schemes	Rainfed Areas	Major Schemes	Minor Schemes	Rainfed Areas
2006	4.63	3.80	3.45	4.51	3.73	3.32
2007	4.84	4.43	3.76	4.82	4.03	3.30
2008	4.80	3.99	3.53	4.60	3.81	3.36
2009	5.00	4.25	3.55	4.58	4.07	3.41
2010	5.29	4.38	3.98	5.00	4.21	3.62
2011	3.82	3.34	2.91	4.91	4.00	3.32
2012	5.20	4.44	3.83	4.50	3.48	3.06
Average	**4.80**	**4.09**	**3.57**	**4.70**	**3.90**	**3.34**

Source: ADB, based on Department of Census and Statistics (2014)
* In first year after completion of relevant irrigation infrastructure

ANNEX 2
ASSUMED INCREASE IN CROPPING INTENSITIES BY SUB-AREA

			Cropping intensities		Cropping intensities		Cropping intensities		Selected Scenario:MCB	
		Area	WOP		WP		WOP	WP	Start of	% Benefits
System	Type	(Ha)	Maha	Yala	Maha	Yala	M+Y	M+Y	Benefits	First year
A	Major	7,050	1.00	1.00	1.00	1.00	2.00	2.00	2023	100%
F	Major	3,000	1.00	1.00	1.00	1.00	2.00	2.00	2023	100%
D2	Major	10,480	1.00	0.99	1.00	1.00	1.99	2.00	2018	100%
E	Major	7,530	0.98	0.97	1.00	1.00	1.95	2.00	2018	100%
I/H	Major	1,052	0.98	0.96	1.00	0.96	1.94	1.96	2023	100%
HFC	Major	2,365	1.00	0.92	1.00	0.92	1.92	1.92	2023	100%
D1	Major	26,520	1.00	0.91	1.00	1.00	1.91	2.00	2018	100%
C	Major	22,800	1.00	0.88	1.00	1.00	1.88	2.00	2020	100%
H	Major	32,180	1.00	0.85	1.00	0.86	1.85	1.86	2023	100%
G	Major	6,210	1.00	0.85	1.00	1.00	1.85	2.00	2018	100%
B-Left Bank	Major	18,500	1.00	0.78	1.00	0.80	1.78	1.80	2020	100%
I/H	Major	520	1.00	0.63	1.00	0.80	1.63	1.80	2023	100%
I/H	Major	3,335	0.94	0.66	1.00	0.80	1.60	1.80	2023	100%
M/H-1	Major	4,210	1.00	0.53	1.00	0.80	1.53	1.80	2023	100%
I-1	Major	607	0.86	0.64	1.00	0.80	1.50	1.80	2023	100%
NWP-1	Major	6,505	0.75	0.45	1.00	0.80	1.20	1.80	2019	100%
NWP-2	Minor	4,987	0.80	0.20	1.00	0.80	1.00	1.80	2023	100%
NWP-2	Minor	1,000	1.00	-	1.00	0.80	1.00	1.80	2023	100%
M/H-2	Major	3,500	1.00	-	1.00	0.80	1.00	1.80	2023	100%
NCP2 (Majo	Major	14,500	1.00	-	1.00	0.80	1.00	1.80	2030	100%
I-1	Major	132	0.70	-	1.00	0.80	0.70	1.80	2023	100%
I-2	Major	2,000	0.70	-	1.00	0.80	0.70	1.80	2023	100%
NCP1 (Mino	Minor	33,000	0.70	-	1.00	0.80	0.70	1.80	2030	100%
I-1	Major	2,525	0.41	0.10	1.00	0.80	0.51	1.80	2023	100%
B-Right Banl	Major	10,000	-	-	1.00	0.80	-	1.80	2023	100%
D1 Kaudulla	Major	1,420	-	-	1.00	1.00	-	2.00	2018	100%
D1-Kantale	Major	6,576	-	-	-	1.00	-	1.00	2018	100%
TOTAL		**232,504**	**0.86**	**0.57**	**0.97**	**0.89**	**1.42**	**1.86**		

ANNEX 3
IDENTIFYING THE IMPACT OF IMPROVED IRRIGATION ON PADDY YIELD: AN ECONOMETRIC ANALYSIS

A. Introduction

A3.1 **Specification of paddy production function.** The Socio Economics and Planning Centre of the Department of Agriculture conducts bi-annual surveys (one in Maha and one in Yala) on the cost of cultivation of major agricultural products. Each survey covers several hundreds of farmers and collects detailed information on yields, type of irrigation, input costs and farm gate prices. This section presents the results of an analysis of the explanatory variables of paddy yields, based on 140 of such surveys undertaken during 2008-2012, representing the results from about 15,000-20,000 interviews. To better understand the relationship between paddy yields and various agricultural inputs, the following Cobb-Douglas production function was estimated:

$$\ln(Y_i) = \beta_0 + \beta_1\ln(X_{1it}) + \beta_2\ln(X_{2it}) + \beta_3\ln(X_{3it}) + \beta_4\ln(X_{4it}) + \beta_5\ln(X_{5it}) + \beta_6\ln(X_{6it}) + \beta_7\ln(X_{7it}) + \beta_8 D_{1it} + \beta_9 D_{2it} + u_{it}$$

where ln denotes logarithms to base e and

- Y: output (kg/acre)
- X_1: pre-harvest labor (SLRs/acre)
- X_2: pre-harvest machinery (SLRs/acre)
- X_3: seed (kg/acre)
- X_4: phosphorous applied (kg/acre)
- X_5: nitrogen applied (kg/acre)
- X_6: potassium applied (kg/acre)
- X_7: cost of plant protection (SLRs/acre)
- D_1: irrigation (dummy variable: irrigated 1, rainfed 0)
- D_2: water stress reported (dummy variable: yes 1, no 0)
- u: error term, assumed to be independently and identically distributed
- i: area of observation
- t: year of observation (2008: 0, 2009: 1, 2010: 2, 2011: 3, 2012: 4)
- β_{0-9}: coefficients to be estimated

The production function was estimated separately for Maha and Yala, based on survey data for 2008-2012 (a detrended version of the model was also run). In the absence of data on physical inputs related to plant protection and machinery, cost data were used. Because data were available on a per acre basis, and not per plot, the extent of land was not included as a separate input variable.

A3.2 **Summary of estimation procedure.** For both Maha and Yala, 70 observations were available (14 observations per year for 2008-2012). Robust regression models were applied to the data using Stata 13 MP. P-values below 0.05 were considered statistically significant.

A3.3 **Interpretation of estimation results.** For both models (Maha and Yala), coefficients β_{0-9} were estimated, including their standard errors and t-statistics. Coefficients from logged independent variables ($X_{1,2,\ldots,7}$) represent the percentage increase in the dependent variable associated with a 1% increase in the independent variable in its original scale. For unlogged dependent variables (D_1 and D_2), 100 * the coefficient provides an estimate of the percentage increase in the outcome. The values of these parameters can therefore be used to estimate: (i) the increase in paddy output as a result of moving from rainfed to irrigated agriculture, and (ii) the increase in inputs associated with an estimated increase in output.

B. Results

A3.4 **Yala, adjusted for time trend.** The results of the regression model for the Yala season, adjusted for a time trend, are summarized in Table A3.1. Volume of seed, nitrogen applied and whether or not irrigation was used were all significantly associated with output. The coefficient for seed was 0.299, which indicates that for a 10% increase in seed volume, output increased by 2.99% (t=4.06, p<0.001). Similarly, a 10% increase in the volume of nitrogen applied was associated with a 2.52% increase in output (t=3.46, p=0.001). The coefficient of both inputs was less than 1, which indicates diminishing returns. In areas where irrigation was used the output was 31.8% higher than where it was not (t=6.74, p<0.001). None of the other factors in the model, i.e. pre-harvest labor, pre-harvest machinery, phosphorus level, potassium level, cost of plant production or presence of water stress were statistically associated with output. There was also no significant trend in production observed over time. The R-squared value was 0.692 meaning that 69.2% of the variation in outcome was explained by the variables in the model.

Table A3.1: Estimation of Production Function in Yala, Adjusted for Time Trend

Parameter	Variable	Beta	se	t	p-value
β_0	Constant	2.856	1.432	1.99	0.051
β_1	Pre-harvest labor(log(SLRs/ha))	-0.081	0.065	-1.24	0.219
β_2	Pre-harvest machinery(log(SLRs/ha))	0.219	0.133	1.65	0.105
β_3	Seed(log(kg/ha))	0.299	0.074	4.06	<0.001
β_4	Phosphorus applied(log(kg/ha))	-0.071	0.131	-0.54	0.592
β_5	Nitrogen applied(log(kg/ha))	0.252	0.073	3.46	0.001
β_6	Potassium applied(log(kg/ha))	0.132	0.077	1.71	0.093
β_7	Cost of plant protection(log(SLRs/ha))	0.197	0.129	1.53	0.130
β_8	Irrigated	0.318	0.047	6.74	<0.001
β_9	Water stress reported	-0.035	0.026	-1.35	0.183
β_{10}	Time	-0.006	0.012	-0.50	0.617
	R-squared	0.692			

Source: ADB, based on Socio Economics and Planning Centre of the Department of Agriculture (2008-2012)

A3.5 **Yala, fully adjusted for time.** The analysis within the Yala season was repeated with time fully adjusted for in the model (Table A3.2). The results were similar to the model allowing for a time trend, with the exception of the effect of pre-harvest machinery on output. This effect became statistically significant, and an increase of 10% in the machinery level was associated with a 2.52% increase in level of output (t=2.11, p=0.040). The effect of seed volume, nitrogen volume and irrigation were similar to the previous model with a 10% increase in seed volume associated with 3.22% increase in output (t=4.83, p<0.001), nitrogen volume with a 2.59% increase (t=4.00, p<0.001) and the use of irrigation associated with a 30.7% increase (t=7.20, p<0.001). Again, the coefficients of seed and nitrogen volumes indicated diminishing returns. Pre-harvest labor, phosphorus volume, potassium volume, the cost of plant protection and water stress were not statistically significantly associated with output. When time was fully adjusted for, the modeled parameters accounted for 71.0% of the variation in output (R-squared=0.710)

Table A3.2: Estimation of Production function in Yala, Fully Adjusted for Time

Parameter	Variable	Beta	se	t	p-value
β_0	Constant	2.595	1.323	1.96	0.055
β_1	Pre-harvest labor(log(SLRs/ha))	-0.098	0.059	-1.66	0.102
β_2	Pre-harvest machinery(log(SLRs/ha))	0.252	0.120	2.11	0.040
β_3	Seed(log(kg/ha))	0.322	0.067	4.83	<0.001
β_4	Phosphorus applied(log(kg/ha))	-0.048	0.116	-0.42	0.679
β_5	Nitrogen applied(log(kg/ha))	0.259	0.065	4.00	<0.001
β_6	Potassium applied(log(kg/ha))	0.092	0.070	1.31	0.195
β_7	Cost of plant protection(log(SLRs/ha))	0.224	0.130	1.73	0.089
β_8	Irrigated	0.307	0.043	7.2	<0.001
β_9	Water stress reported	-0.040	0.023	-1.73	0.088
	Time (ref=2008)				
β_{10}	2009	-0.073	0.036	-2.04	0.046
β_{11}	2010	-0.034	0.041	-0.82	0.414
β_{12}	2011	0.003	0.041	0.07	0.945
β_{13}	2012	-0.086	0.047	-1.84	0.071
	R-squared	0.710			

Source: ADB, based on Socio Economics and Planning Centre of the Department of Agriculture (2008-2012)

A3.6 **Maha, adjusted for time trend.** The analysis was repeated using data from the Maha season and the results of the model adjusted for an overall time trend (Table A3.3). Pre-harvest machinery, volume of seed, phosphorus and nitrogen and irrigation were significantly associated with output. A 10% increase in pre-harvest machinery was associated with a 6.8% increase in output (t=5.06, p<0.001), see volume with a 3.04% increase (t=4.24, p<0.001), and nitrogen volume with a 4.66% increase (t=4.99, p<0.001). Somewhat surprisingly, increasing phosphorus was associated with a reduction in output, with a 10% increase associated with a reduction of 4.02% (t=-2.69, p=0.009). In areas that were irrigated the output was 35.9% higher in those that were not. There was also a significant time trend (t=-4.04, p<0.001) with the average output decreasing over time by an average of 6.9% per year. The factors in the model accounted for 69.9% of the variation in output in Maha.

A3.7 **Maha, fully adjusted for time.** Finally, the model was applied to the Maha season with time fully adjusted for (Table A3.4). The findings were similar to those from the model adjusted for trend, although phosphorus volume applied became non-significant (t=-1.02, p=0.313). A 10% increase in pre-harvest machinery was associated with an increase of 4.72% (t=4.71, p<0.001), a 2.84% increase for seed volume (t=5.14, p<0.001) and 3.56% increase for nitrogen volume (t=5.18, p<.0.001). In the trend model, the cost of plant production was borderline significant (t=1.91, p<0.061) and significant once time was fully accounted for (t=3.28, p=0.002) with an increase of 10% associated with an increase in output of 4.0%. In areas that were irrigated the output was on average 32.1% higher than for areas that were not (t=8.37, p<0.001). Differences in output by year were also observed, with the lowest production occurring in 2011, when it was 48.5% lower than in 2008, the year with the highest production. The modeled parameters accounted for 73.7% of the variation in output.

Table A3.3: Estimation of Production Function in Maha, Adjusted for Time Trend

Parameter	Variable	Beta	se	t	p-value
β_0	Constant	-1.692	1.517	-1.12	0.269
β_1	Pre-harvest labor(log(SLRs/ha))	0.046	0.074	0.62	0.537
β_2	Pre-harvest machinery(log(SLRs/ha))	0.680	0.134	5.06	<0.001
β_3	Seed(log(kg/ha))	0.304	0.072	4.24	<0.001
β_4	Phosphorus applied(log(kg/ha))	-0.402	0.149	-2.69	0.009
β_5	Nitrogen applied(log(kg/ha))	0.466	0.093	4.99	<0.001
β_6	Potassium applied(log(kg/ha))	0.077	0.091	0.85	0.401
β_7	Cost of plant protection(log(SLRs/ha))	0.180	0.094	1.91	0.061
β_8	Irrigated	0.359	0.052	6.97	<0.001
β_9	Water stress reported	0.026	0.027	0.97	0.334
β_{10}	Time	-0.069	0.017	-4.04	<0.001
	R-squared	0.699			

Source: ADB, based on Socio Economics and Planning Centre of the Department of Agriculture (2008-2012)

Table A3.4: Estimation of Production Function in Maha, Fully Adjusted for Time

Parameter	Variable	Beta	se	t	p-value
β_0	Constant	-0.591	1.230	-0.48	0.633
β_1	Pre-harvest labor(log(SLRs/ha))	0.008	0.056	0.15	0.882
β_2	Pre-harvest machinery(log(SLRs/ha))	0.472	0.100	4.71	<0.001
β_3	Seed(log(kg/ha))	0.284	0.055	5.14	<0.001
β_4	Phosphorus applied(log(kg/ha))	-0.133	0.130	-1.02	0.313
β_5	Nitrogen applied(log(kg/ha))	0.356	0.069	5.18	<0.001
β_6	Potassium applied(log(kg/ha))	0.044	0.071	0.61	0.545
β_7	Cost of plant protection(log(SLRs/ha))	0.400	0.122	3.28	0.002
β_8	Irrigated	0.321	0.038	8.37	<0.001
β_9	Water stress reported	0.016	0.019	0.81	0.419
	Time (ref=2008)				
β_{10}	2009	-0.142	0.057	-2.5	0.015
β_{11}	2010	-0.180	0.072	-2.48	0.016
β_{12}	2011	-0.485	0.075	-6.46	<0.001
β_{13}	2012	-0.289	0.077	-3.77	<0.001
	R-squared	0.737			

Source: ADB, based on Socio Economics and Planning Centre of the Department of Agriculture (2008-2012)