Australian Government

Australian Centre for International Agricultural Research

Final report

project	**Managing groundwater access in the central highlands (Tay Nguyen), Vietnam**
date published	May 2009
project number	SMCN/2002/015
prepared by	Professor Jeff Bennett The Crawford School of Economics and Government, The Australian National University Jeremy Cheesman The Crawford School of Economics and Government, The Australian National University
co-authors/ contributors/ collaborators	Professor Tran Vo Hung Son Ho Chi Minh City University of Economics, Madam Tran Thi Hue Ministry of Natural Resources and Environment
approved by	Dr Gamini Keerthisinghe
report number	FR2009-10
ISBN	978 1 921531 63 7
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The authors gratefully acknowledge Dr Nguyen Thai Lai, Director General of the Department of Water Resources at the Ministry of Natural Resources and Environment, for co-sponsoring this project. We are thankful for the cooperation and support of Dak Lak Peoples' Committee, Dak Lak Department of Agriculture and Rural Development, Dak Lak Department of Environment and Natural Resources, and Buon Ma Thuot Water Supply Company. We thank Truong Dang Thuy and Doan Kim Thanh from Ho Chi Minh City University of Economics for their contributions towards the economic research completed during the project, plus the graduate students from Ho Chi Minh City University of Economics and Tay Nguyen University who were enumerators for four household surveys completed during the course of the project. We are grateful to Dave D'haeze from EDE Consulting Asia Pacific (Hanoi) for commenting on early survey drafts, providing secondary research data and giving valuable insights about smallholder coffee production processes in Dak Lak. We thank Dr Céline Nauges from the Toulouse School of Economics, LERNA-INRA for her constructive comments on several report drafts. Finally, we thank the households in Dak Lak who participated in the surveys for their time and cooperation.

2 Executive summary

2.1.1 Introduction

The development of a sustainable water management regime in Dak Lak Province in the Central Highlands of Viet Nam is one of eighteen high national priority projects in the Implementation of the National Water Resources Strategy for 2006-10. Viet Nam is the second largest coffee producer in the world, and approximately forty percent of national coffee output originates from Dak Lak Province. Coffee production in Dak Lak in recent years has been significantly constrained by dry season water shortages, and the sustainability of smallholder coffee production in the region has been questioned. Moreover, households and other sectors using water, including the environment, have also experienced significant dry season water supply constraints. There is limited scope in Dak Lak to increase water supply with new economically viable water supply infrastructure. On the other hand, opportunities to better manage water using demand side and water planning interventions are prospective but underdeveloped. The implementation of demand side and integrated water resource planning and management in Dak Lak is partly held back by the scarcity of information about the economic value of water in its main usages and social preferences for allocating water for public good purposes, such as environmental flows. Further, the understanding of surface and groundwater systems in Dak Lak is incomplete, as is the understanding of how surface and groundwater systems would likely respond to water reallocations. Understanding of water use efficiencies in the main water using sectors in Dak Lak is also limited.

2.1.2 Motivation and core project activities

The ACIAR funded project 'Managing Groundwater Access in the Central Highlands, Viet Nam' contributes towards the development of a sustainable water management regime in the Dak Lak Plateau of Viet Nam by identifying practical approaches to manage and reallocate scarce water within the Dak Lak Plateau to increase social welfare. The overarching methodological approach taken to identify social welfare increasing water reallocations was based in extended social cost-benefit analysis. Six core project activities were undertaken to develop the minimum knowledge required to be able to identify social welfare increasing water reallocations within the Plateau. These project activities were

- Estimating the demand and marginal economic value of irrigation water in smallholder coffee production, dry season irrigated rice production, and household usages.
- Evaluating whether irrigation water use efficiency can be increased over the short-run on the coffee and rice smallholdings that dominate the Dak Lak Plateau.
- Estimating the monetised preference strength of households to allocate additional water in-situ in the Dak Lak Plateau for public good environmental purposes.
- Evaluating household willingness to pay to support public programs aiming to strengthen hydro-agro-environmental ecosystem functioning in the Dak Lak Plateau.
- Estimating the change to aggregate social welfare in the Dak Lak Plateau from reallocating dry season water.
- Evaluating institutional options for achieving the social welfare increasing water allocations.

2.1.3 Core conclusions

Increasing irrigation water use efficiency on coffee smallholdings in Dak Lak would generate sizable social welfare increases to inhabitants. Coffee smallholders are found to be inefficient irrigators, applying more than twice the amount of water required to

maximise coffee yields. By adopting a technically efficient irrigation schedule, water input could be reduced from the current average application of around 1,050 litres per tree per irrigation to 550 litres per tree per irrigation. Achieving this water input would increase output per hectare by around one half tonne to five tonne on average, and would also reduce variable irrigation costs by around 10 percent on average. Simulating a Plateau wide increase in irrigation water use efficiency on coffee smallholdings shows that increasing water use efficiency in the coffee smallholder sector should also increase producer welfare by stabilizing coffee production as a result of reducing the severity and extent of dry season water shortages in the Dak Lak Plateau. Project research also demonstrates that households in the Dak Lak Plateau are willing to pay around VND30,000 per annum toward programs that increase irrigation water use efficiency on coffee smallholdings, given an expectation of positive hydrologic and environmental spillover effects from this program. Hydrological modeling completed during the project shows that increasing irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau would marginally increase the conjunctive water balance of the Plateau, as well as minimum and average dry season flows in two of the largest rivers in the Plateau. These results suggest that increasing water use efficiency on coffee smallholdings in the Dak Lak Plateau should also marginally increase the resilience, productivity, and stability of the hydrological system, which would have beneficial effects for dependant environmental systems.

Increasing the municipal water price to offset operating costs would increase the financial sustainability of supply but have negligible impact on total municipal water demand and household water expenditure. The project demonstrated that urban household demand for water is extremely unresponsive a changing municipal water price. Household water demand in the Dak Lak Plateau is shown to increase with size, income, and water storage infrastructure, among other factors. These results have implications for water planning and demand management as the size of urban centers increase and households become more affluent. Project research demonstrated that increasing the municipal water price to offset the operating costs of the municipal water supply company in Buon Ma Thuot is feasible, and would have negligible impact on total municipal water demand or water expenditure as a percentage of the average household budget. Increasing the municipal water price would increase the likelihood that water supply infrastructure will be adequately maintained however. A second finding is that the majority of urban households in Buon Ma Thuot did not know the municipal water price, with the result that their demand for municipal water would be insensitive to price changes.

Reducing water input in irrigated rice production by increasing irrigation water use efficiency or encouraging rice smallholders out of production is likely to be welfare increasing. By using simulations, the project showed that the irrigation water use efficiency of irrigated rice plots during the dry season could be increased by around 25 percent compared to current water consumption. The profit incentive for increasing irrigation water use efficiency is very limited on average however, perhaps less than 10 percent.

2.1.4 Core recommendations

Programs to increase irrigation water use efficiency in the smallholder coffee sector are required and would be welfare increasing. Increasing water use efficiency in the smallholder coffee sector is a cornerstone for income stabilization in the coffee smallholder sector, and also for potentially increasing the sustainability of the hydrological system in the Dak Lak Plateau. Coffee farmers do not appear to know the dose response relationship between water and coffee output, and over-irrigate by a factor two times as a result. Developing effective institutions that can bring about greater irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau is therefore strongly recommended. While pricing or some other form of supply constraint is one feasible component of a program to increase irrigation water use efficiency in the coffee smallholder sector, such institutions cannot be implemented on a stand-alone basis

because they will not by themselves reveal the marginal economic value of water to coffee smallholders. In other words, price alone cannot tell farmers the production relationship between timed water input and coffee yield. Moreover, any irrigation water pricing scheme in Dak Lak would likely incur high transaction costs resulting from the difficulty in monitoring groundwater extractions from private smallholder wells, which is the dominant source of irrigation water in the smallholder coffee sector. Previous attempts to price groundwater, price water within irrigation systems, to license groundwater extraction, and establish water user associations to strengthen collective water management have failed in Dak Lak (Ahmad 2000). A more feasible and realistic approach to increasing irrigation water use efficiency on coffee smallholdings in the immediacy therefore is through farmer education. A key recommendation from this research then is to establish pilot programs training coffee smallholders in irrigation water management. Because the project research showed that coffee smallholders also over-fertilize, a comprehensive coffee smallholder training program that includes good irrigation and fertilizer and other farm management practices is recommended. Further, because households in Dak Lak have shown they are willing to pay for programs that increase irrigation water use efficiency on coffee smallholdings, some form of funding arrangement based on direct contributions could be considered.

Re-price urban water to achieve financial sustainability. The second recommendation is that in order to become financially sustainable, the municipal water supply company in Buon Ma Thuot should alter the municipal water price to at least offset operating costs. While the municipal water supply company currently charges a constant tariff for every cubic meter of water supplied to the household, an alternative tariff structure may be preferable. Economic efficiency is served when the long run marginal cost (LRMC) of municipal water supply is equal to the price. LRMC represents the actual cost of augmenting the water supply system to cater for growing demand, but excludes the sunk cost of existing assets. In order to send a signal about the cost of new water supplies, the water industry in Australia and elsewhere in the world have adopted two-part tariffs, in which the volumetric charges reflect the long-run marginal cost of supply and the separate service charge (usually fixed) recovers all remaining administrative and sunk asset costs. Alternatively, increasing block tariffs are often favored in developing countries because the basic water uses undertaken by the poor are internally subsidized using this rate structure (Boland and Whittington 1998). Further, because project research shows that households in Dak Lak are generally not aware of the municipal water price, the municipal water supply company should improve the price information content of household water bills. Increasing the price information content of household water bills has been shown to increase the elasticity of household water demand by up to 30 percent in developed economies (Gaudin 2006). We also recommend that the Buon Ma Thuot water supply company would benefit from guidance on the most appropriate municipal water pricing structure and also the price information content of household water bills, given their lack of expertise in these areas.

Reallocate irrigation water out of dry season irrigated rice production. The 200,000 ML of dry season water currently used in irrigated rice production motivate two recommendations, given the low marginal and average value of water the project finds that rice production has compared to in coffee, household, and other usages. First, efforts should be made to encourage rice farmers to shift out of rice production during the dry season and into other less water intensive crops that can be cultivated on compact soils. Second, the physical and economic feasibility of using submergence non-submergence irrigation in the Dak Lak Plateau should be investigated further, which would likely require field experimentation. We have not investigated the whether either of these initiatives have been explored in the past in the Dak Lak Plateau.

Continue support for programs and projects that effectively drive national water Laws and policies through to on the ground application. The final recommendation is that water policy and planning in Viet Nam should be continued to be strengthened by encouraging more projects similar to this one that effectively drive formal water laws, policies, and

institutions into on the ground application. While Viet Nam's Law on Water Resources, its supporting Decrees, and the multitude of Ministries, Departments, Agencies, and Institutes charged with implementing the Law provide a formal set of institutions for national water resource management, the linkage between formal institutions and practical on the ground regional and local water planning and management can be currently rightly viewed as tenuous. This project research utilized the Law on Water Resources as a guiding framework to identify social welfare increasing water reallocations, with the welfare increasing reallocations coming primarily from achieving greater irrigation water use efficiency in the coffee sector. While Viet Nam's Law on Water Resources calls for the management of water resources based on the principles of rational, economical, efficient, fair, and reasonable water exploitation (Articles 4.1, 20), basin planning based on real regional water potential (Article 20.1), and includes provisions requiring economical and efficient water usage (Article 23.1.b), to our knowledge ours is the first project in Viet Nam to apply these principles analytically to define prescriptive welfare increasing water reallocations. Ostrom (1992) distinguishes institutions as the working rules in use for a water resource, as distinct from formal rules of law and supporting administrative agencies. In Viet Nam there is a dislocation between the working rules in use for water resources on the ground and the formal rules of Law defined by the upper level of the water management institutional hierarchy. Projects that draw through the underlying principles of the Water Law into on the ground planning, analysis, and prescriptive policy formation, such as this project, will strengthen the Water Law and the capacity of national institutions to implement it, and will also bring formal and working rules for managing water resources in Viet Nam closer together.

3 Background

Viet Nam is the second largest coffee producer in the world, with exports in 2007 of approximately one million metric tons (http://www.ico.org/prices/po.htm). Approximately forty percent of Viet Nam's coffee output originates from the Dak Lak Plateau in the Central Highlands region. The Dak Lak Plateau is now dominated by intensive smallholder coffee production, and appears to be increasingly facing binding dry season water constraints caused by the combination of the dry season irrigation water requirements of coffee, the expansion and intensification of coffee production in the Plateau, rapid sustained economic and population growth, and a sustained downward historical trend in annual precipitation. The mature water supply economy in the Dak Lak Plateau offers limited opportunity to develop more economically viable large-scale water supply infrastructure. In contrast, demand side approaches to manage the scarce water resources of the Plateau are at best in their formative stages. Viet Nam's now ten year old Law on Water Resources (1998) ratifies the use of demand side approaches to manage national water resources based on the principles of rational, economical, efficient, fair, and reasonable water exploitation (Articles 4.1, 20). The Law requires basin planning based on real regional water potential (Article 20.1), and includes provisions requiring economical and efficient water usage (Article 23.1.b), that water users implement water saving measures (Article 26.2), and also take measures to prevent and overcome droughts (Article 43.2). Moreover, the National Water Resources Strategy of Viet Nam for 2006-10 targets achieving a sustainable water management regime in Dak Lak as a high priority project, given water scarcity in Dak Lak places real constraints on future regional growth (Socialist Republic of Vietnam 2006).

The implementation of demand side and integrated water resource planning and management in the Dak Lak Plateau is partly held back by the scarcity of information about the economic value of water in its main usages in the Plateau and social preferences for allocating water for public good purposes, such as environmental flows. Further, the understanding of surface and groundwater systems in the Plateau is incomplete, as is the understanding of how surface and groundwater systems would likely respond to water reallocations. The extent to which water is used efficiently in the main usage sectors of the Plateau is also very limited.

4 Objectives

The overarching project aim as set out in the project proforma was to

“develop institutional structures to encourage adoption of the resource mix with the highest net social benefit over the assessment period, with net social benefit being defined in terms of the economic efficiency of agriculture and other economically productive activities, social acceptability and equity and environmental impacts.”

Specific objectives in support of the overarching objective were

- To understand the dynamics of groundwater flows, surface groundwater relationships and sustainable groundwater levels in the Tay Nguyen region of Vietnam, particularly in the Dak Lak Plateau, and to employ these data to analyse the physical impacts of alternative water use regimes over the forecast period.
- To determine the use allocation of groundwater resources that provide for social improvement on the basis of economic, social, and environmental criteria using extended cost-benefit analysis.
- To consider policy options to achieve improved groundwater use practices, and determine the most practical and cost-effective institutional framework to provide incentives for the improved use.
- To facilitate the use of the research findings in the development of policy initiatives and institutional frameworks.
- To build the capacity of Vietnamese individuals and organisations involved in resource and environmental management.

Objectives 1-3 requires

- An understanding of the economic value of water in all usages.
- The capacity to simulate regional surface and groundwater system functioning, and to predict hydrologic system dynamics following water reallocations.
- An understanding of the real potential to increase regional water use efficiency through behavioral, technical, structural, and institutional interventions in the water using sectors; and
- An understanding of the practical feasibility of different institutional and policy interventions to achieve water reallocations.

5 Methodology

The overarching methodological approach taken to identify social welfare increasing water reallocations was based in extended social cost-benefit analysis and the New Institutional Economics. Given project budget, resource, and time constraints, six core project activities were undertaken to develop the minimum knowledge required to be able to identify social welfare increasing water reallocations within the Plateau. These project activities were

- Estimating the demand and marginal economic value of irrigation water in smallholder coffee production, dry season irrigated rice production, and household usages.
- Evaluating opportunities to increase irrigation water use efficiency over the short-run on the coffee and rice smallholdings that dominate the Dak Lak Plateau.
- Estimating the monetised preference strength of households to allocate additional water in-situ in the Dak Lak Plateau for public good environmental purposes.
- Evaluating household willingness to pay to support public programs aiming to strengthen hydro-agro-environmental ecosystem functioning in the Dak Lak Plateau.
- Estimating the change to aggregate social welfare in the Dak Lak Plateau from reallocating dry season water.
- Evaluating institutional options for achieving the social welfare increasing water allocations.

For the sake of continuity, the methods used in these six core project research activities are discussed in section 7.

6 Achievements against activities and outputs/milestones

ACIAR funding for this project commenced on 1 January 2005, and the first payment was delayed until April 2005. Before project funding was released in April 2005 the number of project research activities were limited. To compare the actual and planned completion dates for project activities April 2005 is therefore used as the effective project start date, while the Research Report publication date, where applicable, is used as the delivery date for the activity. Where there is no Research Report associated with an activity, the completion date is taken from the ACIAR Annual Project Report.

Objective 1: To understand the dynamics of groundwater flows surface groundwater relationships and sustainable groundwater levels in the Dak Lak Plateau, and to employ these data to analyse the physical impacts of alternative use regimes over the forecast period.

No.	Activity	Outputs/ milestones	Completion date	Comments
1.1	Updated and developed MIKE SHE model capable of describing integrated surface groundwater dynamics.	MIKE SHE baseline hydrologic model of the Dak Lak Plateau	November 2005	Field research and other activities undertaken to update and further develop the MIKE SHE model of the Dak Lak Plateau are a summarised in the project Annual Report to ACIAR for 2005. The baseline MIKE SHE model that simulated surface and groundwater dynamics under the existing land and irrigation water usage was largely completed within the 10 month planning timeframe set out in the project pro-forma.
1.2	Models describing groundwater levels under alternative extraction scenarios over the forecast period.	MIKE SHE alternative irrigation water use scenario models	November 2005; October 2007	Two alternative water usage scenarios were tested, with both simulating increased dry season irrigation water use efficiency on coffee and rice smallholdings in the Plateau. The irrigation water use efficiency scenarios were simulated using approximate irrigation scheduling data in November 2005, and subsequently re-run using empirical irrigation scheduling data from the 2007 smallholder coffee survey, in October 2007. The results of these simulations are discussed in Research Report 7 and section 7 of this Final Report

Objective 2: To determine the use allocation of groundwater resources that provide for social improvement on the basis of economic, social and environmental criteria using extended cost-benefit analysis.

No	Activity	Outputs/ milestones	Completion date	Comments
2.1	Extended social cost-benefit analysis of groundwater use, including direct use, indirect use, and non-use values for a range of extraction scenarios.	Research Report 7	May 2008	Detailed discussion for this project activity is provided in the ACIAR Annual Project Reports covering the periods 1 January 2007 – 20 November 2007 and 1 June 2007 – 31 May 2008, Research Report 7, and Section 7 of this report. The extended cost benefit analysis was implemented by integrating the MIKE SHE hydrological model simulations, with agronomic water yield response functions defined in Activity 2.1.1, and farm economic data, also defined in Activity 2.1.1. From hereafter, the term integrated hydrologic-agronomic-economic cost benefit analysis is used interchangeably with extended cost benefit analysis model. The project intended to directly incorporate non-use values of dry season water in-situ in the integrated hydrologic-agronomic-economic cost-benefit analysis, and that the non-use values for in-situ water would be obtained from the stated preference analysis of non-use values (Activity 2.1.3). In practice, we found we could not implement a stated preference survey instrument in the Plateau to estimate the economic value of in-situ water because respondents did not believe unused water would remain in-situ. The belief that water could not be allocated in-situ was based in the severity of the dry season water scarcity problem in Dak Lak, and the impossibility of regulating surface water withdrawals outside urban centres. The practical result is that a reliable economic value for in-situ water could not be estimated, and therefore this non-use in-situ value could not be incorporated in the cost benefit analysis. As an alternative to estimating economic values of in-situ water, the cost benefit analysis was supplemented by non-monetised hydrologic balance indicator data. Note also that the project had planned to directly estimate the change in consumer welfare from reducing the incidence of dry season water supply outages to urban centres in the Dak Lak Plateau. These additional social welfare estimates were to be based on empirical urban water demand estimates (Activity 2.1.2) and the hydrological model simulation of urban outages. We found however that most urban water is drawn from confined aquifers in fractured basalt, and the dynamics of these water deposits could not be modelled in MIKE SHE, which only models water dynamics in porous media. As a result, these welfare effects could not be explicitly modelled in the integrated hydrologic-economic model and we were limited to discussing likely consumer welfare effects based on changes in water balances between the business as usual (BAU) and increasing water use efficiency scenarios. The extended cost benefit analysis and report was completed 37 months after ACIAR funding was first received in April 2005, thereby exceeding the deadline for this deliverable set out in the project pro-forma by one month.
Sub-activities completed for 2.1				

No	Activity	Outputs/ milestones	Completion date	Comments
2.1.1	Production function modelling of agricultural and forestry inputs and outputs.	Research Report 6 Research Report 4	November 2007 May 2007	Budget, resource, time, and data availability limitations resulted in the production function project research concentrating on the two agricultural crops responsible for consuming the vast majority of water in the Dak Lak Plateau, which are coffee and wetland rice. Combined, these crops account for more than 80 percent of all agricultural land in the study area and greater than 90 percent of all agricultural water use. Coffee A detailed discussion for this project activity, results, an policy implications is provided in the ACIAR Annual Project Report for 1 January 2007 – 20 November 2007, in Project Research Report 7 and section 7 of this Final Report Rice A detailed discussion for this project activity, results, an policy implications is provided in the ACIAR Annual Report for 1 Jan 2006 - 31 December 2006, in Project Research Report 4, and section 7 of this Final Report
2.1.2	Stated preference modelling of domestic consumption. Questionnaire design and administration, data collection, results analysis.	Research Report 3	March 2007	A detailed discussion for this project activity, results, an policy implications is provided in the ACIAR Annual Project Report for 1 Jan 2006 - 31 December 2006, in Project Research Report 3 and section 7 of this Final Report
2.1.3	Stated preference of non-use values. Questionnaire design and administration, data collection, results analysis.	Research Report 5	March 2007	Detailed discussion for this project activity is provided in the ACIAR Annual Project Report for 1 Jan 2006 - 31 December 2006, in Project Research Report 5 and section 7 of this Final Report
2.2	Spatial and temporal description of groundwater extraction practices that provides the highest level of net social benefit for the areas considered.	Research Report 7	May 2008	The integrated hydrologic-agronomic-economic model of the Dak Lak Plateau is based on MIKE SHE, which is a physically distributed hydrological model. The MIKE SHE model provides a spatial and temporal simulation of groundwater and surface water extractions and their hydrologic results. As a result, the social and economic outcomes of different water allocations are also spatially disaggregated. To make the analysis more tractable for water policy makers, agronomic and economic analyses are aggregated the catchment level. This approach allowed the social and economic outcomes of water reallocations to be analysed dor the seven catchments within the Plateau, and also the identification of catchments that stand to gain the most, in hydrologic balance and social welfare terms, from increasing irrigation water use efficiency, to be identified.

No	Activity	Outputs/ milestones	Completion date	Comments
2.3	Provision of information regarding optimal inter-sectoral and inter-temporal water allocation to enable the agriculture, forestry, and urban sectors to improve water resource planning.	Research Report 7	May 2008	The integrated hydrologic-agronomic-economic model identifies how water reallocation in the Plateau changes social welfare. Identifying social welfare maximising water allocations is an unrealistic water policy objective in the Dak Lak Plateau, due to the complexity and diversity of the hydrologic, agronomic, and economic systems and their interactions.

PC = Partner Country, A = Australia

Objective 3: Consider alternative policy options for securing improved groundwater use practices using the New Institutional Economics framework.

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Developed practical institutional framework for governance of water resources in agricultural and forestry sectors that accommodates government environmental policy	Final Project symposium	September 08	Discussions at the symposium were based on the use of the project findings to develop useful policy reform mechanisms

PC = Partner Country, A = Australia

Objective 4: To facilitate the use of the research findings in the development of policy initiatives and institutional frameworks.

No.	Activity	Outputs/ milestones	Completion date	Comments
4.1	Development activities including seminars, conference presentations and briefing session for government officials.		NA	Refer to section 8.4 for communication and dissemination activities.

Objective 5: To build the capacity of Vietnamese individuals and organisations involved in resource and environmental management.

No.	Activity	Outputs/ milestones	Completion date	Comments
5.1	Improved capacity of collaborating individuals and organisations in Vietnam and an increase in the probability of the recommendations of the project being implemented			The resource and environmental management capacity of several collaborating institutions has been strengthened through this project. The Ministry of Natural Resources and Environment has developed its technical capacity in hydrological modelling and integrated hydrologic-agronomic-economic modelling. Further, several staff at MONRE have developed their financial and economic modelling skills by participating in an international training program that was coordinated by the project. Staff and graduate students at Ho Chi Minh City University of Economics and Tay Nguyen University have strengthened their survey, technical, and quantitative skills in natural resource and environmental economics in several ways including: increased capacity for understanding and critically appraising stated preference approaches to non-market valuation in the Vietnamese context; survey design, development, implementation, and analysis; technical writing; and conference speaking.

7 Key results and discussion

7.1 The marginal economic value of irrigation water in coffee production, and irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau.

7.1.1 Research summary and method

Research Paper No. 6 used a marginal productivity approach to estimate the economic value of dry season water as an irrigation input in smallholder coffee production and to identify the potential for increasing irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau. The marginal productivity approach shows how changing input amounts or the timing of inputs alters productivity, for example, how increasing irrigation water input per coffee tree or the timing of dry season irrigations changes the amount of coffee output achieved by the smallholder.

The production analysis was based on a survey of 105 Robusta smallholders unevenly and randomly selected from six districts in the Dak Lak Plateau: Buôn Đôn, Cu' m'gar, Krông Ana, Krông Buk, Krông Pak, and TP Buon Ma Thuot. The survey was completed in early 2007 for the 2005-06 coffee production years. Staff from the Ho Chi Minh City University of Economics, Tay Nguyen University, The Australian National University, and coffee agronomists working in the Dak Lak Plateau jointly developed the survey instrument. Implementation of the survey was lead by Dr Tran Vo Hung Son from the Ho Chi Minh City University of Economics, using graduate students from Ho Chi Minh City University of Economics and Tay Nguyen University as enumerators.

7.1.2 Key results

Average production amongst respondents was approximately four metric tons of green coffee bean per hectare, or roughly 3.8 kilograms per tree.

On average, coffee smallholders over-applied fertilizer compared to the maximum requirements advised by the agricultural extension services in Dak Lak. The advised elemental nutrient requirement for production stage coffee trees in Dak Lak are 0.25 kilograms nitrogen, 0.09 kilograms of phosphorous, and 0.27 kilograms of potassium per tree per annum (Lich et al. 2005). Survey respondents averaged 0.44 kilograms N, 0.19 kilograms P and 0.41 kilograms K per tree.

The average coffee smallholder applied 1,050 litres per tree per irrigation and irrigated 3.8 times during the dry season. This is equivalent to applying about 4,000 litres of irrigation water per tree during the dry season, and 4,200 cubic metres per hectare, assuming an average of 1,050 trees per hectare. These irrigation input amounts are substantially higher than the recommended irrigation amount for maximum coffee yields in Dak Lak, which is between 390 and 650 litres per tree in two to four dry season irrigations, that is between 820 and 2,750 cubic metres per hectare. Only nine survey respondents input less than 650 litres per tree on average per irrigation, which is the irrigation dose advised by Dak Lak DARD.

The statistical production function analysis carried out in Research Paper No. 6 shows that the marginal physical productivity of irrigation water in smallholder coffee production is zero at the average amount used by coffee smallholders in 2005-06. In other words, the production analysis shows that coffee smallholders cannot increase their coffee output by applying more than 550 litres per tree per irrigation. Using more than 550 litres per tree per irrigation is therefore allocatively inefficient for coffee smallholders, because they incur irrigation expenses without making additional revenue.

Irrigation scheduling was found to have a substantial impact on productivity. The statistical production analysis shows the coffee irrigation schedule that maximises yield involves (1) commencing irrigation before mid-January, (2) applying more irrigation water to the tree on the first dry season irrigation in order to stimulate the majority of buds to flower, and (3) spacing irrigations 16 to 21 days apart until the end of the dry season. These results are broadly consistent with experimental results for Robusta production in Dak Lak reported in D'haeze, Deckers et al. (2003). Plot-specific agro-environmental conditions also have a significant impact on coffee output per tree. Coffee smallholders who had pest infestations recorded 20 percent lower output on average compared to those not experiencing infestation. Output is higher per tree on flat land, compared to moderate or steeply sloped land, and output per tree is maximised when the tree is 15 years old. Socio-economic and institutional variables are also influential on output per tree. Fragmentation, measured by the number of plots the smallholder cultivated, decreased output per tree. Producers with registered land titles had higher outputs per tree, as did smallholders with larger farmed areas. Against expectations, smallholders mono-cropping coffee were less productive then their diversified counterparts. Respondents who had received technical irrigation and fertilizer training in the previous twelve months were not more productive than their counterparts.

Production simulations using the estimated production function show that if the statistically average smallholder in the 2005-06 production year had applied 550 litres per tree per irrigation, used a 20-day irrigation interval, and irrigated three times during the dry season, they would have used 1,700 cubic metres of water per hectare during the dry season, achieved around 5 metric tons of coffee output, and increased their 2005-06 coffee profits by around VND15 million per hectare compared to the statistically average coffee smallholder.

7.1.3 Implications for water policy in the Dak Lak Plateau

The main policy implication of the research is that there is substantial scope for micro-basin coffee smallholders in the Dak Lak Plateau to increase irrigation water use efficiency and to lift farm profits as a consequence of doing so. Coffee smallholders can improve their irrigation water use efficiency, increase production output, and reduce irrigation costs by altering their irrigation schedules.

It is not productive to apply more than 550 litres per coffee tree per irrigation in the Dak Lak Plateau because the excess water simply drains away from the root zone. The actual coffee water requirement may be less than this, in the range of 400 litres per tree, however the survey data used in this analysis meant the optimal irrigation water input could not be identified because no coffee smallholders were using this little water. Therefore, the recommended coffee irrigation amount should be reduced from 650 litres to a maximum of 550 litres per tree per application in the Dak Lak Plateau.

To maximize coffee output from irrigation scheduling, coffee smallholders should be advised to (1) begin irrigating before mid-January, (2) apply more irrigation water during the first dry season irrigation in order to stimulate the majority of coffee buds to flower, and (3) space irrigations 16 to 21 days apart until the end of the dry season.

Conservatively assuming that the allocatively efficient dry season irrigation schedule includes three equally spaced irrigations totaling 550 litres per tree per irrigation, a planting density of 1,050 trees per hectare, and 130,000 hectares of Robusta in the Plateau suggests dry season diversions to Robusta could be reduced by around 340,000 ML per annum. As a point of comparison, this demand reduction is roughly equivalent to 30 per cent of the unconfined aquifer’s annual average recharge (Moller 1997: 95). Potential for moving towards a more sustainable and social welfare increasing water management regime in Dak Lak via increased irrigation efficiency on coffee smallholdings is therefore suggested.

7.1.4 Practical applications of the research results

- Irrigation water use efficiency training for coffee smallholders
- Water demand planning for new coffee areas
- Inter-sectoral water allocations in water scarce areas
- Justification to encourage coffee smallholders to purchase and use water flow metres on their irrigation pipes.

7.2 The marginal economic value of irrigation water in dry season rice production, and irrigation water use efficiency on irrigated rice smallholdings in the Dak Lak Plateau

7.2.1 Research summary and method

Research Paper No. 4 used a simulation optimization approach to define the marginal economic value of dry season water in irrigated rice production in the Dak Lak Plateau, to identify the profit maximizing irrigation schedule for irrigated rice during the dry season, and to determine whether the optimal irrigation schedule for wet rice used less water than the locally advised irrigation water input. A simulation optimization approach was used because empirical data that could be used to establish an empirical production relationship between timed water input and rice outputs in the Dak Lak Plateau was lacking. The agronomic simulation model (BUDGET version 2.0) was populated with environmental and crop parameters for Winter-Spring irrigated rice production in the Dak Lak Plateau. Irrigated rice planting dates and crop parameters were obtained from the Dak Lak Department of Agriculture and Rural Development and soil profiles were obtained from field surveys. The simulation production plot soil properties were based on soil profile analyses of paddy plots in Dak Gan reported in D'haeze (2004).

7.2.2 Key results

The validity of the agronomic simulation model's parameters was evaluated by simulating an irrigation of 9,500 cubic meters per hectare under normal climatic conditions after sowing. This is the amount of water input per hectare recommended by local extension authorities for wet rice, net of a 2,500 cubic meter assumed land preparation watering. This irrigation strategy returned an average submergence depth of approximately 12.1 centimetres after the initial saturation period and maximised yield, which was considered an adequate simulation result in the absence of better data.

Compared to locally advised dry season wetland rice water requirements of 12,000 cubic meters per hectare, the results of the simulation optimization model shows that the profit maximizing dry season irrigation schedule with unconstrained seasonal water supplies requires 9,700 cubic meters of water per hectare during a normal climatic year. Rice profits are increased by around 9.5 percent compared to the representative plot using the profit maximizing irrigation schedule, from VND3.15 million to VND3.45 million per hectare. The profit maximizing irrigation schedule for wet rice farmers in the Dak Lak Plateau is a submergence non-submergence schedule (SNS), also known as alternate wetting-drying irrigation. Soil moisture is maintained between saturation and field capacity throughout the entire growth cycle and intermittent submergence occurs but never exceeds one centimeter in depth. This compares to the submergence irrigation currently used in the Dak Lak Plateau, which normally has 10 to 20 centimeters of submergence. The simulations suggest the profit maximizing SNS strategy results in 1,100 cubic meters of irrigation water being lost from the plot to deep percolation. This compares to deep percolation totaling 2,250 cubic meters when locally recommended practices are followed. Further, no surface water is retained on the plot at the end of the cropping season in the SNS strategy, whereas approximately 900 cubic meters is retained following the locally recommended CS strategy.

Based on the simulation optimization results, the short run economic value of dry season irrigation water in irrigated rice production has a choke price of around VND38,300 per cubic meter when the seasonal water stock is constrained at 5,650 cubic meters per hectare after sowing. This value falls in a near linear fashion to VND650 per cubic meter at 7,000 cubic metres per hectare of seasonal supply.

7.2.3 Implications for water policy in the Dak Lak Plateau

The irrigated rice analysis shows that SNS can generate higher crop profits and increase the irrigation water use efficiency of irrigated dry season rice farming compared to the CS method now used by rice farmers in Dak Lak. However, while SNS reduces total on-plot within season water demand substantially, and this potentially creates a social benefit by releasing this excess water to alternative uses, the research shows the profit increase from switching to SNS is small, at less than 10 per cent. SNS has been widely advocated in water policy because it maximises the ratio of water use to applied water in rice production (De Datta 1981; Mao 1996; Zhi 1996; Guera et al. 1998; Nwadukwe and Chude 1998; Tuong and Bhuiyan 1999), however the economics of SNS irrigation have not been investigated. This project research suggests that when water is unpriced, unregulated, and dry season supply is unreliable, which is the case for much of the Dak Lak Plateau, SNS will be a less than convincing irrigation strategy for dry season lowland rice producers because the profit incentive is modest at best. This economic result has a core policy implication for whether broad-scale SNS uptake can be encouraged in regions where water is unpriced and water usage poorly regulated. In a risky production environment where water supplies are uncertain, water diversions are mainly uncontrolled, and irrigators are generally risk adverse, such a small profit gain is unlikely to motivate irrigated rice smallholders to switch over from CS to SNS. While increasing within season plot level water use efficiency may be a prima facie intuitive and persuasive general argument from broader aggregate social welfare and river basin planning objectives, it will likely be viewed as less desirable than the status quo to privately optimising myopic rice irrigators. Successful implementation of broad scale SNS uptake in rice production systems where irrigation water usage is unregulated would therefore require that irrigators believe there is a real potential for positive payoffs to them from adopting SNS. These positive payoffs would most likely take the form of increased water supply reliability.

Water has a marginal economic value in dry season irrigated rice production in the Dak Lak Plateau, but only above the minimum seasonal allocation of 5,650 cubic metres per hectare. Below this level of seasonal irrigation water input, rice producers would be unwilling to pay for dry season irrigation water during a normal or drier climatic year on average, because a profit cannot be generated on one hectare with this amount of water, even when using the efficient SNS irrigation scheduling. The results also suggest that if irrigation water in the Plateau were priced and fully enforced above VND50 per cubic metre, dry season irrigated rice farming would become unprofitable during normal or drier climatic years.

Assuming 16,500 hectares of dry season irrigated rice in the Plateau, reducing water diversions by around 2,300 cubic metres per hectare would release around 38,000 ML for other uses during the dry season.

7.2.4 Practical applications of the research results

- Irrigation water use efficiency training for irrigated rice smallholders
- Water demand planning for new rice areas
- Inter-sectoral water allocations in water scarce areas.

7.3 Household demand for water, and the marginal economic value of water in household use

7.3.1 Research summary and method

Research Paper No. 3 estimated the water demand of households (1) using municipal water exclusively, and (2) households using municipal water and private well water in the

urban and peri-urban areas of Buon Ma Thuot. Understanding household water demand is important for water planning and management in Dak Lak for several reasons. Water supplied to households in Buon Ma Thuot is drawn from springs and production wells located in the deep aquifer in the region east of Buon Ma Thuot, and are located in rice and coffee producing areas. Water diversions for Buon Ma Thuot from these areas negatively affects coffee and rice producers by limiting the amount of water available for irrigation, thereby raising the question of the extent to which these diversions are justified based on the efficiency, rationality, fairness, and sustainability grounds that the Law on Water Resources of Viet Nam calls for in determining water allocations. Understanding household water demand is also important for demand forecasting. Further, because the municipal water price charged by the municipal water supply company does not offset short run operating costs, the water supply company needs to know what implications charging a sustainable price will have on household municipal water demand and also household water expenditure.

Data used in the analysis was gathered through a household survey of 291 urban and peri-urban households in Buon Ma Thuot. Staff from the Ho Chi Minh City University of Economics, Tay Nguyen University, The Australian National University, and staff from the Buon Ma Thuot Water Supply Company jointly developed the survey instrument. Implementation of the survey was lead by Dr Tran Vo Hung Son from the Ho Chi Minh City University of Economics, using graduate students from Ho Chi Minh City University of Economics and Tay Nguyen University as enumerators. The survey used a unique approach to overcome difficulties that arise when estimating household water demand when water is not priced or is fixed priced, as is the case for municipal water supplies in Buon Ma Thuot, which are charged at VND2,250 per cubic metre for household use. This survey approach is discussed in detail in the Research Paper.

7.3.2 Key results

Roughly 55 percent of all respondents reported only using metered municipal water for household activities. Households augmenting municipal water supplies with a second source – either a private well, bottled water and other sources accounted for 11, 13 and 11 percent of respondents respectively. This implies approximately 95 percent of respondent households draw water from no more than two sources, including approximately 80 percent of respondent households using either municipal water exclusively or combining municipal and well water.

For households consuming water from the municipal supply system only, average per capita daily consumption is approximately 125 litres. Households using both municipal and private well water consume approximately 65 litres per capita per day from the municipal system on average and supplement this with approximately 75 litres per capita per day from the household well.

Almost nine out of ten respondent households reported having some form of in-house water storage infrastructure and about two-thirds of these respondents installed this infrastructure before the Buon Ma Thuot water supply project was completed. The most popular form of water storage is in-household cement storage tanks, which were installed in almost seven out of every ten households surveyed. These storage tanks hold an average capacity of approximately 2.5 cubic meters, which is sufficient to supply 4.5 days water for an average-sized household consuming 120 litres per capita per day. Households using water from wells have largely automated the process with approximately 85 percent using motorized pumps with an average pump capacity of 1.2 HP.

Approximately 85 percent of respondents did not know the municipal water tariff.

The own price elasticity of households using municipal water only was -.06, meaning for every one percent increase in the municipal water price these households reduce their monthly municipal household water consumption by 0.06 percent. The result shows

households using municipal water only in Buon Ma Thuot are very unresponsive to changes in the municipal water price. Household size has a positive effect on total monthly municipal water consumption, with a semi-elasticity of 0.60, meaning for every additional household member total monthly household municipal water consumption increases by 60 percent, on average. Further, having in-household water storage, and the in-household water storage capacity also increases monthly household water consumption.

For households consuming both municipal and household well water, own price elasticity was -.51 for municipal water and -.32 for well water. Cross price elasticities were .44 for municipal water and .31 for well water. These results mean that for every one percent increase in the municipal water price, households consuming well and municipal water will, on average, reduce their municipal water consumption by 0.5 percent and increase well water consumption by 0.44 percent. Further, for every one percent change in the well water (shadow) price, households decrease well water consumption by around .3 percent and increase municipal water consumption by 0.3 percent. These results show that these households view water from the municipal and household well as being substitutes, not compliments.

Income elasticity is a significant predictor of household demand for municipal water but not well water. A ten percent increase in monthly household income is approximately commensurate with a 3.5 percent increase in total monthly household water consumption from the municipal source.

The economic value of municipal water to households was estimated by evaluating the impact of reducing monthly dry season municipal supplies to the household. This is a realistic scenario given the rolling municipal water supply shortages that have occurred in Buon Ma Thuot during the recent drought years. For households using municipal supplies only, the marginal value of municipal water rises from approximately VND1,500 for a one cubic meter monthly outage to approximately VND350,000 for a six cubic meter monthly outage. These value estimates reflect that these households have inelastic demand for water because due to the lack of water substitutes. Households consuming municipal and private well water have substantially lower at-source economic values for municipal water, ranging between VND300 and VND5,000 for one and six cubic meter outages respectively, reflecting the ease with which they can switch consumption between water sources.

7.3.3 Implications for water policy in the Dak Lak Plateau

The household water demand estimates show that municipal water pricing would likely be a blunt instrument to manage urban water demand in Buon Ma Thuot, at least over the short term. For the minimum 40 percent of Buon Ma Thuot households using municipal water exclusively, increasing the municipal water tariff would cause these households to only marginally reduce their municipal water consumption. For the minimum 25 percent of households in Buon Ma Thuot augmenting municipal water with well water, increasing municipal water prices would simply cause them to shift out of municipal water consumption into well water consumption. While this result may relieve some pressure on the municipal water supply system, it results in no net change in water consumed in the household.

Municipal water could feasibly be priced for full cost recovery, at least over the short term. Assuming households consuming municipal water only account for 40 percent of all households connected to the municipal water supply system, and further that these households average monthly consumption is around 16 cubic meters, increasing the municipal water tariff to VND4,000 per cubic meter to fully offset the average water supply cost reported by the Buon Ma Thuot water supply company would result in the households consuming municipal water only reducing total monthly consumption by approximately five percent to 15.25 cubic meters, on average. The average monthly municipal water bill for these households would increase from around VND35,955 to VND60,983. Assuming

20,000 households are connected to the municipal supply system suggests monthly revenue from this subgroup would increase from approximately VND288 million to VND488 million. The same price increase would also cause households combining municipal and well water to increase well water consumption by around 4.9 cubic meters per month and reduce municipal water consumption from around 9.1 to 5.5 cubic meters, resulting in their average monthly municipal water bill rising marginally from VND20,520 to VND22,041. Assuming these households account for 25 percent of households with municipal connections in Buon Ma Thuot, monthly revenue increases from VND103 million to VND110 million from this subgroup. For both subgroups, the household budget impact of increasing expenditure on municipal water is modest. Municipal water expenditure as a percentage of average monthly income for households using municipal water exclusively rises from 1.4 to 2.3 per cent, and from 0.08 to 0.09 per cent for households using municipal and household well water.

The final policy implication of the research relates to the role that socio-economic factors and household water supply infrastructure have on household water demand. Increasing household income, size, and in-house water supply infrastructure changes water consumption in all estimates, but the consumption pattern differs notably between households using municipal water only and those using municipal and well water. Households using municipal water only increase their total monthly consumption as their household size and in-household storage capacity increases. Households using municipal and well water increase municipal water consumption as their income increases, and increase their well water consumption as their household size increases, and with increasing in-household water supply infrastructure, in particular well pump capacity. Within a household utility maximising framework, the estimates suggest households use water from wells because they get water of a similar perceived quality, at least throughout the dry season, at a lower cost per cubic metre than municipal water. There are two immediate policy implications here. First, water planners in Buon Ma Thuot should expect increasing household demand for municipal water as households using municipal water exclusively increase in size and add storage capacity. Second, households using both municipal and well water appear to move into municipal water as they become increasingly affluent, but increase well water consumption as their household size increases, and as household well water supply infrastructure is intensified. Perceived declines in well water quality, such as during the wet season, or availability may encourage these households to shift into municipal water however.

7.3.4 Practical applications of the research results

- Municipal water demand planning for urban and peri-urban areas in Dak Lak
- Inter-sectoral water allocations in water scarce areas
- Devising sustainable municipal water pricing.

7.4 Household willingness to pay for an irrigation water use efficiency program generating hydrologic and environmental benefits

7.4.1 Research summary and method

Research Paper No. 5 used a household survey dataset to estimate how much households in the Dak Lak Plateau would be willing to contribute towards a proposed project aiming to increase irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau, and to investigate how respondents' socio-economic attributes, attitudes, and water usage affected willingness to contribute. This research is relevant to water resource management in Dak Lak for several reasons. Because it is unlikely that funds will be forthcoming from the State for irrigation water use efficiency programs in Dak

Lak in the near term, it is desirable to know whether a program could be directly funded. It is also desirable to know whether different policy beneficiaries have systematically different willingness to pay for the proposed program.

Because smallholder coffee irrigation accounts for the vast majority of water used in the Dak Lak Plateau, it is anticipated that increasing water use efficiency on coffee smallholdings would generate hydrologic, agronomic, and environmental impacts that extend beyond the coffee smallholder plot. For example, increasing irrigation water use efficiency on coffee smallholdings may result in more water being held in-situ, and this would like contribute towards increasing dry season baseflows, which would contribute towards riparian system health. Because of these cascading benefits, all households in the Plateau may be willing to pay for the irrigation water use efficiency program to be implemented.

A household survey was used to estimate household willingness to contribute towards the program. Research findings are based on the survey dataset of 165 urban, peri-urban, and rural households in the Dak Lak Plateau. Staff from the Ho Chi Minh City University of Economics, Tay Nguyen University, and The Australian National University jointly developed the survey instrument. Implementation of the survey was lead by Dr Tran Vo Hung Son from the Ho Chi Minh City University of Economics, using graduate students from Ho Chi Minh City University of Economics and Tay Nguyen University as enumerators. Enumerators from the Ho Chi Minh City University of Economics and Tay Nguyen University administered the survey. The survey used a novel approach to overcome the difficulty in asking households to estimate how much they would be willing to contribute towards a novel program that had uncertain outcomes. The program has uncertain outcomes because of incomplete technical information about the hydrology of the Dak Lak Plateau, the relationships between hydrologic states and agro-ecosystem functioning, and also because of the impact of random external impacts on hydrologic and agro-environmental system performance, most notably the role of weather.

7.4.2 Results summary

Nearly 30 percent of respondents reported their reference river drying out during the dry season and more than 90 percent of respondents using groundwater reported that the dry season groundwater condition, expressed in terms of groundwater head elevation and well exhaustion, had deteriorated over the last five years. Households that reported observing either reducing dry season low flows in their reference river or a worsening in the dry season groundwater condition mainly attributed these changes to either deforestation, natural variability in wet season rainfall, or irrigated agriculture. These results indicate that, prima facie, households do not view dry season coffee irrigation on smallholdings in the Dak Lak Plateau the main cause of water shortages in the Dak Lak Plateau. Most households did view dry season irrigated agriculture as one of the three main causes for dry season surface and groundwater conditions however.

Respondents also demonstrated preferences for allocating water in-situ in order to maintain hydrologic system functions for the current and future generations, meaning they want to allocate water for public good purposes. Approximately 95 percent of the respondents stated that river health was important even if they had never visited or intended to visit that river in the Plateau. All respondents at least agreed with the sentiment that their current generation was responsible for maintaining river health for the benefit of future generations.

Effectively all respondents had a positive willingness to pay for the proposed program. The willingness to contribute estimate showed that coffee smallholders were less willing to pay for the proposed irrigation efficiency program. This result was surprising given the null hypothesis that these respondents potentially stand to gain the most in monetary benefit terms. However the estimates show that the lower willingness to pay of coffee farmers is progressively offset as coffee farm size increases. Smallholders cultivating more than 1.75 hectares are more willing to pay for the program than respondents who do not classify

themselves as coffee farmers, whereas coffee farmers operating on less than 1.75 hectares are less willing to pay for the proposed program, all other factors constant. Households became more willing to contribute to the proposed program as their average monthly household income and highest education level increases. Underlying motivations also clearly affected willingness to pay. Respondents who indicated natural resource management issues are one of the most pressing problems facing the Plateau stated they were more willing to contribute to the program, as were respondents within increasingly strong existence and bequest preferences. Respondent views about the causes of dry season water scarcity in the Plateau also clearly motivated willingness to pay. Respondents believing the groundwater situation had become worse during the past five years and attributing this situation primarily to irrigation have higher willingness to pay. In contrast, respondents viewing the dry season water situation primarily resulting from natural variability in wet season rainfall or the result of deforestation were less willing to pay for the program. Respondents believing the water resource situation would get worse in the future than the scenario described without the program demonstrated higher willingness to pay. Similarly, respondents who believed that coffee farmers could reduce their irrigation water use without having a negative impact on yields were more willing to pay for the program.

After adjusting for biases, the median willingness to pay to pay for the irrigation water use efficiency training program amongst survey respondents was VND29,192 per annum. Over the proposed five years of the program, the median household willingness to contribute to the program is approximately VND145,000 before discounting. This central tendency willingness to contribute shifts with changing levels of socio-economic, attitudinal, and experiential attributes, with some of these reported in Research Paper No. 5.

7.4.3 Implications for water policy in the Dak Lak Plateau

Several key policy implications stem from the novel approach used to test household willingness to pay for a program to indirectly increase social welfare through improved hydrologic, agricultural, and environmental conditions in the Dak Lak Plateau. The analysis suggests households in the Dak Lak Plateau are willing to pay VND145,000 over five years for irrigation water use efficiency training program to be implemented on coffee smallholding in the Dak Lak Plateau, given an expectation that this program would also deliver hydrologic and agro-environmental benefits. This household willingness to pay estimate can be used as the basis for evaluating the financial feasibility of an irrigation water use efficiency program in the Dak Lak Plateau.

The fact that coffee smallholders holding less than 1.75 hectares are less willing to pay than all other groups may flag challenges in implementing a payment program. Without overextending conjecture it is difficult to explain the result that coffee farmers were found to be less willing to pay for the proposed program, given coffee smallholders likely stand to gain the most immediate and private benefits, in terms of reducing production costs from increasing irrigation efficiency. Historically, coffee smallholders in Dak Lak have received farm extension from both government and other agencies generally free of charge. Against this prior entitlement background, the lower willingness to pay of coffee farmers may reflect an inferred right for receiving the proposed training free or charge.

The estimates suggest motivations and household endowments matter in terms of how much the household is willing to contribute to the proposed irrigation water use efficiency program. Most respondents agreed or strongly agreed with the sentiment that they are responsible for protecting resources for future generations, a finding buttressed by the valuation function estimates showing respondents are increasingly willing to pay for the program as the strength of the bequest motivation increases. The result may suggest one avenue for motivating the program is appealing to an obligation towards future generations.

7.4.4 Practical applications of the research results

- Cost benefit analyses and funding of irrigation water use efficiency training programs
- Evaluating inter-sectoral water allocations in water scarce areas
- Encourage public private partnerships or private suppliers to enter the coffee smallholder extension market in Dak Lak.

7.5 Increasing social welfare in the Dak Lak Plateau by reallocating water

7.5.1 Research summary and method

Research Paper No. 7 evaluated whether improvements in social welfare and hydrologic balances in the Dak Lak Plateau could be achieved by reallocating dry season water by increasing irrigation water use efficiency on coffee and rice smallholdings.

An integrated hydrologic-agronomic-economic model developed for the analysis. The bio-economic model utilised the coffee crop production analysis from Research Paper No. 6 and the rice production analysis from Research Paper No. 4. The Bureau of Groundwater Resource Management at the Ministry of Natural Resources and Environment developed the hydrologic model with consulting support from DHI International. Development of the hydrology model included field visitations by MONRE staff to the Dak Lak Plateau in 2005 in order to obtain ground and surface water observation data, to ground-truth the location and features of key water supply infrastructure, and to brief staff at the Dak Lak Ministry of Agriculture and Rural Development and Department of Natural Resources and Environment on the project. After the hydrology model was developed, it was calibrated and was shown to be able to acceptably simulate groundwater and dry season surface water flows.

Three scenarios were evaluated for the period 1998-2003: a baseline status quo (BSQ) scenario and two scenarios with increased irrigation water use efficiency on coffee and rice smallholdings. Irrigation input and timing in the BSQ scenario was based on the statistically average irrigation scheduling practices and water input observed on coffee and rice smallholdings in the Plateau, and was taken from Research Reports Nos. 4 and 6. Irrigation input and timing for the two increased irrigation water use efficiency scenarios were based on the technically and allocatively efficient water input defined in Research Reports Nos. 4 and 6.

The integrated hydrologic-agronomic-economic cost benefit analysis constitutes is a large step towards the integrated river basin planning objective of the Law on Water Resources (Article 20.1), and also identifies whether increasing water use efficiency on coffee and rice smallholdings will move the Dak Lak Plateau towards a sustainable water regime, which is a high national priority of Viet Nam's 2006-10 National Water Resources Strategy.

7.5.2 Results summary

Results show increasing irrigation water use efficiency, primarily on coffee smallholdings in the Plateau, would increase social welfare in the Dak Lak Plateau. The welfare improvements would come in part from the reduction in coffee smallholder irrigation costs, however most of the gains would come from reducing the severity and duration of water shortages that otherwise imposed binding production constraints on coffee farmers by limiting their ability to irrigate.

Approximately 55,000 hectares of approximately 150,000 hectares (37 per cent) of the coffee area in the Dak Lak Plateau was simulated to experience irrigation water supply shortages during the six-year simulation in Scenarios One and Two, compared to 66,000

hectares (45 per cent) in the BSQ scenario. Water supply shortages reduce average coffee output in the BSQ scenario to 4.1 metric tons per hectare, compared to 4.8 metric tons in Scenario One, and 4.6 metric tons in Scenario Two. Total output for 1998 to 2003 in the BSQ scenario is approximately 3.6 million metric tons (600,000 metric tons per annum on average), compared to 4.3 million metric tons (710,000 metric tons per annum on average) in Scenario One and 4.05 million metric tons in Scenario Two (675,000 metric tons per annum on average). The standard deviation of annual output in the BSQ scenario was 57,000 metric tons, 7,000 tons in Scenario One, and 21,000 metric tons in Scenario Two. Collectively, the results show that the irrigation schedule in Scenario One minimises coffee yield losses from water deficit, and also minimises output variability caused by stochastic weather conditions. The simulations showed rice yields are essentially unaffected by water deficits in all scenarios.

The production benefits from using water in smallholder coffee and dry season rice production are largest in Scenario One, totaling approximately VND24.3 trillion between 1998 and 2003, followed by Scenario Two (VND22.6 trillion), and the BSQ scenario (VND17.4 trillion). Excepting in 2002, coffee production accounts for more than 95 per cent of annual operating surplus in each scenario, totaling VND24.1 trillion in Scenario One, VND22.3 trillion in Scenario Two, and VND17.2 trillion in the BSQ case. Less than five per cent of irrigated rice area is impacted by water deficits in all three Scenarios. Further, the irrigation deficit effect on aggregate smallholder operating profit is equal across Scenarios.

The simulations suggest that increasing irrigation water use efficiency on coffee smallholdings would only marginally improve the hydrologic balance of the Dak Lak Plateau.

Annual groundwater recharge in the Plateau averaged 1.2 million ML in the BSQ scenario, which is identical to average recharge estimated in Moller (1997). Seventy to 90,000 ML more recharge occurred annually on average in the BSQ scenario compared to Scenario One and Two, with this difference being the return flows of excess water from coffee irrigation. The Plateau wide demand for water for dry season coffee irrigation averaged 515,000 ML per annum in the BSQ scenario, exceeding the 360,000 ML volume estimated as being available in the Plateau's upper unconfined aquifer by a factor of 1.43 times. Simulated coffee water extractions in the BSQ scenario were 370,000 ML per annum on average. Combined with Moller's (1997) assessment of the accessible groundwater resource, these results suggest that the accessible resource of the unconfined aquifer is being fully exploited by coffee irrigators in the BSQ scenario, on average. In spite this exhaustion pattern the average annual saturated storage was simulated to increase by around 796,000 ML between 1998 and 2003. Between 1999 and 2001, the average annual saturated zone storage increased by around 2.5 per cent per annum before shifting to a zero growth rate in 2002 and 2003. The pattern of saturated zone storage change was positively correlated to rainfall intensity. Average Plateau-wide depth to the groundwater table fluctuated within a 1.5 metre range around 13 metres each year in the BSQ scenario, and is generally increasing over time, consistent with the increasing saturated zone storage.

Demand for water in coffee irrigation averaged 305,000 ML in Scenario One and 230,000 ML per annum in Scenario Two. Withdrawal averaged 272,000 ML and 209,000 ML per annum for Scenario One and Two respectively, which showed that around 90 per cent of smallholder irrigation water demands were met in these simulations. The upper unconfined aquifer stock increased by 808,000 ML in Scenario One between 1998 and 2003, and by 822,000 ML in Scenario Two, and followed the same dynamics in both Scenarios as the BSQ case. Between 1998 and 2003, an additional 19,000, 25,000, and 27,000 ML of surface water was simulated coming into storage in the BSQ, Scenario One, and Scenario Two consecutively, meaning the total change in the conjunctive water stock of the Plateau was 815,000 ML in the BSQ scenario, compared to an 833,000 ML stock increase in Scenario One and a 849,000 ML increase in Scenario Two.

Social welfare and hydrologic balance analyses were completed for the six subcatchments within the Dak Lak Plateau: Krong Buk, Ea Mroh, Ea Tul, West BMT, Ea Tam, and Ea Pour. Rice was excluded from the subcatchment analysis because the difference in operating surpluses and water usage between the scenarios was shown to be numerically immaterial in each subcatchment.

Results revealed several commonalities between subcatchments. The differences in coffee operating surpluses between scenarios were predominantly caused by the severity of irrigation water shortages faced by coffee farmers, and irrigation costs did not change substantially between the scenarios because there was little difference in (ground)water table depths. The second common feature between subcatchments was that the differences in hydrologic balances between the scenarios were generally minor, which showed that increasing irrigation water use efficiency on coffee and rice smallholdings had little effect on the hydrologic balances of the individual subcatchments of the Plateau.

On a per hectare basis, Krong Buk had the most profitable coffee production in the Plateau in the BSQ simulation, with a weighted average operating surplus totaling VND162 million per hectare for 1998 to 2003. The weighted average total BSQ operating surplus in the neighbouring Ea Tam and Ea Pour subcatchments were VND120 million, falling to VND100 million per hectare in Ea Tul, VND90 million in Ea Mroh, and VND67 million per hectare in the shallow basalt subcatchment of West BMT. Increasing irrigation efficiency on coffee smallholdings increased the simulated weighted average operating surplus per hectare in Scenario One and Scenario Two in all subcatchments. For 1998 to 2003, the average per hectare operating surplus in Scenario One totaled VND166 million in Krong Buk, Ea Tul, Ea Pour, and Ea Tam, VND155 million in West BMT, and VND142 million in Ea Mroh. The higher per hectare operating surpluses in Scenario One and also Scenario Two resulted primarily from coffee smallholders achieving higher output as a result of not facing binding irrigation water constraints. In Scenario One, yield averaged 4.8 kilograms or greater per tree for coffee area experiencing water shortages. Total operating surplus per hectare in Scenario Two equaled Scenario One for Krong Buk, Ea Pour and Ea Tam, were ten per cent lower in Ea Tul (VND148 million) and West BMT (VND141 million), and thirty per cent lower in Ea Mroh (VND100 million).

7.5.3 Implications for water policy in the Dak Lak Plateau

The core policy implication is that the results of the integrated hydrologic-agronomic-economic cost benefit analysis establish a strong policy case based on increasing aggregate social welfare for increasing irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau. The integrated hydrologic-agronomic-economic cost benefit analysis shows that increasing dry season irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau would increase aggregate social welfare in the Plateau relative to the status quo water allocation in 1998 to 2003. Setting total dry season irrigation water demand per coffee tree at 2,300 litres during a dry year and 1,750 litres during a normal or wetter year resulted in total operating surpluses from coffee increasing by a factor of 1.4 times for the Plateau compared to the BSQ case. Lowering seasonal demand per tree to 1,750 litres during dry years and 1,350 during normal or wetter years increased total operating surpluses by a factor of around 1.3 times compared to the BSQ case. Increasing irrigation water use efficiency eliminated water supply shortages for around 10,000 hectares of coffee in the Plateau, and also reduced the incidence and severity of water supply shortages on the remaining 55,000 hectares of coffee where dry season water supply shortages persisted. Increasing irrigation water use efficiency also stabilised coffee output in all subcatchments with the exception of Krong Buk, where water shortages were not pronounced in the baseline simulation. While the reliability and availability of water for coffee irrigation increases with increasing irrigation water use efficiency on coffee smallholdings, only a marginal improvement in the hydrological balance occurs, at around 2.2 per cent in Scenario One and 4.3 per cent in Scenario Two for 1998-2003. Combined with the increasing flow results in Krong Buk and Ea Tul rivers, these results provide weak support for an argument that increasing water

use efficiency on coffee smallholdings in the Plateau could marginally increase hydro-agro-ecosystem resilience, productivity, and stability in the Plateau, in addition to generating increasing producer surpluses from coffee production. Research Paper No. 5 showed that groundwater and surface water have positive in-situ utility in the Plateau. Therefore, any increase in dry season ground and surface water stocks and flows compared to the business as usual case will be welfare increasing, even though a monetised estimate for these welfare improvements cannot be estimated.

A second core policy implication is that most of the welfare gains from increasing irrigation water use efficiency on coffee smallholdings accrue directly to coffee smallholders. The result that welfare gains from increasing irrigation efficiency appear to be largely isolated to near where the more efficient irrigation water use is being practiced has policy implications for targeting those who should potentially pay for these programs.

A third core policy implication is that some subcatchments appear to stand to gain more from interventions that increase irrigation water use efficiency on coffee smallholdings and consistently, some subcatchments are clearly more marginal for producing coffee due to their dry season water availability. Noting that the following discussion is based on averages and therefore should be viewed as broad observations, results of the integrated cost benefit analysis suggest all subcatchments other than Krong Buk would benefit from programs that increased irrigation water use efficiency on coffee smallholdings. The simulation results suggest Krong Buk has effectively no marginal coffee producing land area, defining marginal land here as smallholders operating on land facing real, as opposed to perceived, irrigation water shortages compared to the actual water requirements for Robusta. Increasing irrigation efficiency in Krong Buk would have effectively no change on production or welfare outcomes within the subcatchment, other than to potentially marginally increased welfare from increasing dry season river flows. In all other subcatchments, programs to increase irrigation water use efficiency will deliver more substantial social welfare gains.

The fourth policy issue is dry season irrigated rice production. The simulation estimates show operating surpluses for dry season irrigated rice do not change except for the reduced volumetric irrigation costs between the scenarios. Decreasing surface water depths on lowland rice during the dry season also has no observable impact on the hydrologic balance of the Plateau. Water allocated to dry season irrigated rice production averages 230 million cubic metres per annum in the Plateau in the BSQ case, which is roughly 45 per cent of the total irrigation water usage of coffee. An economic rationale for allocating water currently used in dry season irrigated rice into higher value usages exists. In Ea Kmir for example, coffee smallholders affected by water supply shortages incurred a production loss between 1998 and 2003. Dry season irrigation water supplies for coffee production fell short of demand by approximately 4.5 million cubic metres on average in the BSQ scenario, peaking in the 1998 and 2003 drought years at six million cubic metres. On average, the coffee water demand shortfall is less than 20 per cent of the 28 million cubic metres of water used in dry season rice irrigation per annum on average in Ea Kmir. Ignoring any possible reallocation costs, reallocating dry season surface water from rice to fully satisfy coffee demands could have increased the total operating surplus for 1998 to 2003 to VND570 billion from VND275 billion in the BSQ scenario at an opportunity cost of around VND14 billion in foregone rice production.

7.5.4 Practical applications of the research results

- Integrated water resource planning as required by the Law on Water Resources
- Evaluating inter-sectoral water allocations in water scarce areas of the Plateau

8 Impacts

8.1 Scientific impacts – now and in 5 years

A scientific impact is the change in scientific practices that have occurred outside the project because of the findings of the project.

At the time of writing the project is yet to change scientific practices outside of the project. Note however that the project has been innovative in the methods developed to:

- Estimate the technical efficiency of irrigation water usage
- Estimate household water demand when water prices are invariant
- Measure household preferences for the supply of public goods, and also measure how much households would financially contribute towards policy programs that aim to provide public goods.

The project team is confident that within the next five years these methodological advances will utilized by other water resource and environmental economic researchers. The methodological innovations are communicated through the project Research Reports and conference presentations. Potentially more significantly in terms of their capacity for scientific impact, the project's innovative research methods are in the process of being published in leading high impact technical journals. The household water demand analysis has been accepted as a journal article in *Water Resources Research*, which in 2007 had the second highest ISI Impact Factor and Citation rating of water resource management journals, and the highest Half Life. The approach used to measure social preferences for public goods is in revise and resubmit status with *Environmental and Resource Economics,* an influential and high ranking environmental and resource economics publication. The approach used to estimate technical efficiency of irrigation water usage in coffee production is a forthcoming publication in *Forest, Trees, and Livelihoods.* The project team are confident that disseminating the methodological innovations of the project through these well regarded and high impact publications will result in their uptake in future research outside the project.

8.2 Capacity impacts – now and in 5 years

The capacity impacts of the project are substantial within all partner organisations in Viet Nam.

In the Bureau of Surface and Groundwater Management at the Ministry of Natural Resources and Environment core staff have developed skills in the development of hydrological modeling applications using MIKE SHE and MIKE 11. Staff have also developed a deep understanding of the hydrology of the Dak Lak Plateau, and the relationships between land and water usage and hydrological dynamics. It is anticipated that both MIKE SHE and the Dak Lak Plateau model will be used for water planning in the future at MONRE. Moreover, through formal training completed as part of the project core staff in the Department of Water Resources Management at MONRE have developed skills in economic and financial modeling, and now apply these skills in non-project related work. Finally, and perhaps most importantly, staff at MONRE have gained from completing their first prescriptive integrated water resource management project. Integrated water resource management is a process promoting the coordinated development of land and water resources to maximize economic and social welfare (Jakeman and Letcher 2003). While the Viet Nam Law on Water Resources requires the integrated management of water resources, water planning at the Ministry has historically had a hydrology and engineering focus. This ACIAR project was the first at MONRE to

integrate economic and institutional analysis with hydrologic and land use systems in order to identify social welfare increasing water reallocations.

At Ho Chi Minh City University of Economics, the Department of Development Economics has developed a strong skill platform in stated preference analysis, which is the underlying method employed in the household water demand and preferences for public goods analyses, and would now be regarded as the leading institution in Viet Nam in developing and applying these methods, and probably also the leading institution in the Mekong region. Core staff in the Development Economics faculty at the HCMCUE have also developed their capacity to conduct technical efficiency analysis, which is a fundamental method for analyzing the efficiency of agricultural production. Moreover, core staff at HCMCUE have strengthened their ability to undertake complex household surveys in rural areas of Viet Nam, and graduate students who were household survey enumerators have had the opportunity to experience how household surveys are properly implemented.

At Tay Nguyen University core staff have strengthened their ability undertake complex household surveys in rural areas of Viet Nam, and graduate students who were household survey enumerators have had the opportunity to experience how household surveys are properly implemented.

We also note that the relationships developed at the senior level between MONRE and HCMCUE during the course of the project will likely lead to future collaborative water economics research between these two institutions, and that this will likely feed into Viet Nam's water policy process over time. We also note that in 2008 the Department of Water Resources Management at the Ministry of Natural Resources and Environment established a Bureau of Economics and Information, which is charged with collecting and using economic information for water resources planning. We are confident that during the next five years HCMCUE and the Bureau of Economics and Information will collaborate on water economics research projects, and that research findings from these collaborations will progressively become more linked to the process of water policy formation.

Several non-partner organisations have developed capacity as a result of this project. In particular, staff from the Institute of Water Resources Planning in Hanoi received training and hands on development experience with the MIKE SHE hydrology application, and also increased their capacity for integrated hydrologic-economic modeling using GAMS.

8.3 Community impacts – now and in 5 years

The socioeconomic and environmental impacts of this research project are likely to be substantial if core recommendations forthcoming from the project are implemented.

8.3.1 Socio-economic impacts

The key socioeconomic impacts of specific recommendations are:

- Research Report 6 estimates that shifting from average to efficient irrigation practices on coffee smallholdings in Dak Lak would, on average, increase production by around 500 kilograms per hectare per annum, reduce dry season irrigation water input by 2,300 cubic meters per annum, and reduce short run on farm irrigation costs by VND2.7 million per annum. Moreover, the integrated hydrologic-agronomic-economic modeling reported in Research Report 7 show that increasing dry season irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau increased operating surpluses from coffee by a factor of 1.4 times compared to the baseline case, from VND17.4 trillion to VND24.3 trillion between 1998 and 2003 through a combination of reduced irrigation costs, and increased yields due to a reduction in the incidence of irrigation water shortages. Caveats on these estimates are discussed in Research Report 7. Even before estimating the cost of implementing programs to effect irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau it is evident that the gains from such a program would exceed the costs by a sizeable margin over a five year implementation timeframe.
- The water supply company in Buon Ma Thuot estimates it needs to set water prices at an average of VND4,000 per cubic meter to offset operating costs. Research Report 3 estimated that increasing the municipal water price to VND4,000 would have a marginal impact on household municipal water consumption, and further, the impact on household budgets would be minimal, on average. Research Report 3 also demonstrated household water shortages generate sizable social welfare losses, in particular for households using municipal water exclusively. If the municipal water supply company cannot recover operating costs over the medium term there is a risk, acknowledged by the water supply company, that municipal water supply infrastructure will not be able to be completely maintained, and this could cause increasing supply disruptions. Implementing sustainable municipal water prices in Buon Ma Thuot and other urban centers in the Dak Lak Plateau could therefore yield a double dividend over the coming years, first by allowing the water supply companies to offset their operating costs, and second by securing more reliable household water supplies, which would be social welfare increasing even after taking into account the impact of the increased household municipal water costs.

8.3.2 Environmental impacts

The integrated hydrologic-agronomic-economic modeling in Research Report No. 7 suggests that increasing irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau would marginally increase the conjunctive water balance of the Plateau. Minimum and average dry season flows in two of the largest rivers in the Plateau were simulated as increasing by more than 10 percent when irrigation water use efficiency was increased, with these simulations also suggesting some flow stabilization during severe drought periods. Assuming results for these two rivers are indicators of what will likely occur in other surface water systems in the Plateau, a reasonable but not testable assumption is that minimum and average dry season flows in other rivers in the Plateau will also increase in aggregate. These results provide weak support for an argument that increasing water use efficiency on coffee smallholdings in the Dak Lak Plateau should also marginally increase the resilience, productivity, and stability of the hydrological system, which would have beneficial effects for dependant environmental systems in the coming years.

8.4 Communication and dissemination activities

The discussion in this section is separated into communication and dissemination activities that have been completed at the time of preparing this report, and those planned for completion as part of the project.

8.4.1 Completed communication and dissemination activities

Project research findings have mainly been disseminated through the combination of printed material and through presentations and briefs. Printed material includes:

- Project research reports, which are available in hard copy from MONRE or on-line through the project website. Each research report is accompanied by a project research brief that summarises the main research findings in non-technical language. These research briefs are available in English and Vietnamese
- Journal publications
- Presentation and briefings have focused at the level of key policy decision-makers in Hanoi and Dak Lak
- Three project progress meetings were held in Hanoi in 2005, 2006, and 2008. These meetings brought together all project partners and invited personnel from organisations involved in managing land and water resources in Dak Lak
- Mid-term project presentations were made to Dak Lak DARD, and Dak Lak DONRE in 2006 in Buon Ma Thuot. These presentations summarized the main findings from the coffee, rice, and integrated hydrologic-agronomic modelling
- The Buon Ma Thuot Water Supply Company was briefed on the urban water research in 2006, and were involved in planning the research
- Project research and findings have been presented at international fora including
- A research presentation at AusAID in Canberra in 2005
- A research presentation at Ho Chi Minh City University of Economics in 2008
- Research presentations at the 2006 and 2007 annual conferences of the Australian Agricultural and Resource Economics Society.

8.4.2 Planned communication and dissemination activities

At the time of writing additional communication and research dissemination activities are being planned with collaborating project partners in Viet Nam in order to drive the core project research findings into the formation of water management policies and programs in Dak Lak, and also to disseminate the research findings more widely.

Communication of the project reports and their findings has been facilitated through the preparation of 'research briefs'. These single page documents have been prepared in both English and Vietnamese and professionally edited to increase the penetration into the policy making process. They were printed in colour after being professionally graphic designed and distributed to the key government agencies for further distribution.

The project research, website http://www.crawford.anu.edu.au/staff/jb_vietnam.php, and research reports will be pushed further into the public domain by linking into electronic networks that focus on water resources and development, such as the Australian Development Gateway http://www.developmentgateway.com.au/jahia/jsp/index.jsp, http://water.developmentgateway.org, and enviro-vlc - Environment in Viet Nam and the Region, a widely subscribed email list for professionals working in the environment sector in Viet Nam. The research project will be featured on the Department of Water Resource Management website http://www.dwrm.gov.vn/en/index.php?cires=News&in=viewst&sid=10, and a permanent link to the project's research website.

Organisations have been targeted to receive communications about specific components of the research. The production function and irrigation water use efficiency research for coffee will be communicated to the Viet Nam Coffee and Cocoa Association (Vicofa), which is currently undertaking sustainable coffee initiatives in Dak Lak http://www.ede-consulting.de/about_us/EDE%20Asia%20Pacific/Support%20to%20rolling%20out%20sustainable%20coffee%20initiatives%20in%20Dak%20Lak%20province and to Dak Lak DARD. The

results of the rice research, which suggest the potential for increasing irrigation water use efficiency through alternate submergence non-submergence irrigation will be communicated to Dak Lak DARD. The Boun Ma Thuot Water Supply Company will receive a full briefing on the results of the household water demand analysis. The objective is to encourage these organisations to develop practical and implementable policy based on our research results.

Project research findings will be communicated directly with organisations involved in larger scale water resource planning and management in Viet Nam. These include the Asian Development Bank, who is currently undertaking an integrated water planning project in the Srepok basin, which encompasses Dak Lak http://pid.adb.org:8040/pid/TaView.htm?projNo=40082&seqNo=01&typeCd=2, and the German Federal Ministry of Education and Research, who, in cooperation with the Southern Institute of Water Resources Research and Lam Don Department of Natural Resources and Environment are currently undertaking an integrated water resources management project in Lam Don province which forms the South-East border of Dak Lak http://www.iwrm.vn/index.php?page=1 . The objective is to have these organisations integrate the findings of our research into their integrated water planning efforts.

9 Conclusions and recommendations

9.1 Conclusions

Increasing irrigation water use efficiency on coffee smallholdings in Dak Lak would generate sizable social welfare increases to inhabitants. Coffee smallholders in Dak Lak are inefficient irrigators, applying more than twice the amount of water required to maximise coffee yields. By adopting a technically efficient irrigation schedule, water input could be reduced from the current average application of around 1,050 litres per tree per irrigation to 550 litres per tree per irrigation. Achieving this water input could increase output per hectare by around one half tonne to five tonne per hectare on average, and would also reduce variable irrigation costs by around 10 percent on average. Simulating a Plateau wide increase in irrigation water use efficiency on coffee smallholdings shows that increasing water use efficiency in the coffee smallholder sector should also increase producer welfare by stabilizing coffee production as a result of reducing the severity and extent of dry season water shortages in the Dak Lak Plateau. Project research also demonstrates that households in the Dak Lak Plateau are willing to pay around VND30,000 per annum toward programs that increase irrigation water use efficiency on coffee smallholdings, given an expectation of positive hydrologic and environmental spillover effects from this program. Hydrological modeling completed during the project shows that increasing irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau would marginally increase the conjunctive water balance of the Plateau, as well as minimum and average dry season flows in two of the largest rivers in the Plateau. These results suggest that increasing water use efficiency on coffee smallholdings in the Dak Lak Plateau should also marginally increase the resilience, productivity, and stability of the hydrological system, which would have beneficial effects for dependant environmental systems.

Increasing the municipal water price to offset operating costs would increase the financial sustainability of supply but have negligible impact on total municipal water demand and household water expenditure. The project demonstrates that urban household demand for water is extremely unresponsive a changing municipal water price. Household water demand in the Dak Lak Plateau is shown to increase with size, income, and water storage infrastructure, among other factors. These results have implications for water planning and demand management as the size of urban centers increase and households become more affluent. Project research demonstrated that increasing the municipal water price to offset the operating costs of the municipal water supply company in Buon Ma Thuot is feasible, and would have negligible impact on total municipal water demand or water expenditure as a percentage of the average household budget. Increasing the municipal water price would increase the likelihood that water supply infrastructure will be adequately maintained however. A second conclusion is that the majority of urban households in Buon Ma Thuot did not know the municipal water price, with the result that their demand for municipal water would be insensitive to actual tariff changes.

Reducing water input in irrigated rice production by increasing irrigation water use efficiency or encouraging rice smallholders out of production is likely to be welfare increasing. By using simulations, the project shows that the irrigation water use efficiency of irrigated rice plots during the dry season could be increased by around 25 percent compared to current water consumption. The profit incentive for increasing irrigation water use efficiency is very limited on average however, perhaps less than 10 percent.

9.2 Recommendations

Programs to increase irrigation water use efficiency in the smallholder coffee sector are required and would be welfare increasing. Increasing water use efficiency in the

smallholder coffee sector is a cornerstone for income stabilization in the coffee smallholder sector, and also for potentially increasing the sustainability of the hydrological system in the Dak Lak Plateau. Coffee farmers do not appear to know the dose response relationship between water and coffee output, and over-irrigate by a factor two times as a result. Developing effective institutions that can bring about greater irrigation water use efficiency on coffee smallholdings in the Dak Lak Plateau is therefore strongly recommended. While pricing or some other form of supply constraint is one feasible component of a program to increase irrigation water use efficiency in the coffee smallholder sector, such institutions cannot be implemented on a stand-alone basis because they will not by themselves reveal the marginal economic value of water to coffee smallholders. In other words, price alone cannot tell farmers the production relationship between timed water input and coffee yield. Moreover, any irrigation water pricing scheme in Dak Lak would likely incur high transaction costs resulting from the difficulty in monitoring groundwater extractions from private smallholder wells, which is the dominant source of irrigation water in the smallholder coffee sector. Previous attempts to price groundwater, price water within irrigation systems, to license groundwater extraction, and establish water user associations to strengthen collective water management have failed in Dak Lak (Ahmad 2000). A more feasible and realistic approach to increasing irrigation water use efficiency on coffee smallholdings in the immediacy therefore is through farmer education. A key recommendation from this research then is to establish pilot programs training coffee smallholders in irrigation water management. Because the project research showed that coffee smallholders also over-fertilize, a comprehensive coffee smallholder training program that includes good irrigation and fertilizer and other farm management practices is recommended. Further, because households in Dak Lak have shown they are willing to pay for programs that increase irrigation water use efficiency on coffee smallholdings, some form of funding arrangement based on direct contributions could be considered.

Re-price urban water to achieve financial sustainability

The second recommendation is that in order to become financially sustainable, the municipal water supply company in Buon Ma Thuot should alter the municipal water price to at least offset operating costs. While the municipal water supply company currently charges a constant tariff for every cubic meter of water supplied to the household, an alternative tariff structure may be preferable. Economic efficiency is served when the long run marginal cost (LRMC) of municipal water supply is equal to the price. LRMC represents the actual cost of augmenting the water supply system to cater for growing demand, but excludes the sunk cost of existing assets. In order to send a signal about the cost of new water supplies, the water industry in Australia and elsewhere in the world have adopted two-part tariffs, in which the volumetric charges reflect the long-run marginal cost of supply and the separate service charge (usually fixed) recovers all remaining administrative and sunk asset costs. Alternatively, increasing block tariffs are often favored in developing countries because the basic water uses undertaken by the poor are internally subsidized using this rate structure (Boland and Whittington 1998). Further, because project research shows that households in Dak Lak are generally not aware of the municipal water price, the municipal water supply company should improve the price information content of household water bills. Increasing the price information content of household water bills has been shown to increase the elasticity of household water demand by up to 30 percent in developed economies (Gaudin 2006). We also recommend that the Buon Ma Thuot water supply company would benefit from guidance on the most appropriate municipal water pricing structure and also the price information content of household water bills, given their lack of expertise in these areas.

Reallocate irrigation water out of dry season irrigated rice production

The 200,000 ML of dry season water currently used in irrigated rice production motivate two recommendations, given the low marginal and average value of water the project finds that rice production has compared to in coffee, household, and other usages. First,

efforts should be made to encourage rice farmers to shift out of rice production during the dry season and into other less water intensive crops that can be cultivated on compact soils. Second, the physical and economic feasibility of using submergence non-submergence irrigation in the Dak Lak Plateau should be investigated further, which would likely require field experimentation. We have not investigated the whether either of these initiatives have been explored in the past in the Dak Lak Plateau.

Continue support for programs and projects that effectively drive national water Laws and policies through to on the ground application. The final recommendation is that water policy and planning in Viet Nam should be continued to be strengthened by encouraging more projects similar to this one that effectively drive formal water laws, policies, and institutions into on the ground application. While Viet Nam's Law on Water Resources, its supporting Decrees, and the multitude of Ministries, Departments, Agencies, and Institutes charged with implementing the Law provide a formal set of institutions for national water resource management, the linkage between formal institutions and practical on the ground regional and local water planning and management is currently tenuous. This project research utilized the Law on Water Resources as a guiding framework to identify social welfare increasing water reallocations, with the welfare increasing reallocations coming primarily from achieving greater irrigation water use efficiency in the coffee sector. While Viet Nam's Law on Water Resources calls for the management of water resources based on the principles of rational, economical, efficient, fair, and reasonable water exploitation (Articles 4.1, 20), basin planning based on real regional water potential (Article 20.1), and includes provisions requiring economical and efficient water usage (Article 23.1.b), to our knowledge ours is the first project in Viet Nam to apply these principles analytically to define prescriptive welfare increasing water reallocations. Ostrom (1992) distinguishes institutions as the working rules in use for a water resource, as distinct from formal rules of law and supporting administrative agencies. In Viet Nam there is a dislocation between the working rules in use for water resources on the ground and the formal rules of Law defined by the upper level of the water management institutional hierarchy. Projects that draw through the underlying principles of the Water Law into on the ground planning, analysis, and prescriptive policy formation, such as this project has done, will strengthen the Water Law and the capacity of national institutions to implement it, and will also bring formal and working rules for managing water resources in Viet Nam closer together.

10 References

10.1 References cited in report

Ahmad, A. 2000. An Institutional Analysis of Changes in Land Use Pattern and Water Scarcity in Dak Lak Province, Vietnam. Nordic Conference on Institutions, Livelihoods and the Environment: Change and Response in Mainland Southeast Asia, University of Lund, Copenhagen.

Boland, J. J. and Whittington, D., 1998. *The political economy of increasing block tariffs in developing countries*, EEPSEA Special Papers Series Singapore.

De Datta, S. K., 1981. *Principles and Practices of Rice Production*, Wiley, New York.

D'haeze, D., 2004. Water management and land use planning in the Central Highlands of Vietnam. The case of Coffea canephora in Dak Lak province, PhD Thesis, Leuven University, Faculteit Landbouwkundige en Toegepaste, Leuven.

D'haeze, D., Deckers, J., Raes, D., Phong, T. A. and Chanh, N. D. M., 2003. 'Over-irrigation of Coffea Canephora in the Central Highlands of Vietnam revisited. Simulation of soil moisture dynamics in Rhodic Ferralsols', *Agricultural Water Management*, 63:185-202.

Gaudin, S., 2006. 'Effect of price information on residential water demand', *Applied Economics*, 38(4):383 - 93.

Guera, L. C., Bhuiyan, S. I., Tuong, T. P. and Barker, R., 1998. *Producing more rice with less water from irrigated systems*, International Rice Research Institute Discussion Paper No. 29, Manila.

Jakeman, A. J. and Letcher, R. A., 2003. 'Integrated assessment and modelling: features, principles and examples for catchment management', *Environmental Modelling & Software*, 18(6):491-501.

Lich, L. H., Tuan, B. and D'haeze, D., 2005. *Technical training of trainers module 3: Fertilizer management*, PPP Project: Promotion of Sustainable Robusta Production in Dak Lak Buon Ma Thuot.

Mao, Z. 1996. Environmental impact of water-saving irrigation for rice. Irrigation Scheduling: From Theory to Practice - Proceedings of the ICID/FAO Workshop on Irrigation Scheduling, Food and Agriculture Organisation of the United Nations, Rome.

Moller, K. N., 1997. *Hydrogeology and water resources of the Dak Lak Plateau*, Action Plan for Water Resources Development Phase III, Upper Srepok Basin, Vietnam. Working Paper 19, Hanoi.

National Assembly of the Socialist Republic of Vietnam, 1998. *No. 8/1998/QH10: The Law on Water Resource*, Hanoi**:** http://www.dwrm.gov.vn/en/index.php?cires=Laws&in=lawsdetail&id=1.

Nwadukwe, P. O. and Chude, V. O., 1998. 'Manipulation of the irrigation schedule of rice (Oryza sativa L.) as a means of maximizing water use efficiency and irrigation efficiency in the semi-arid tropics', *Journal of Arid Environments*, 40(3):331-39.

Ostrom, E., 1992. *Crafting Institutions for Self-Governing Irrigation Systems*, International Center for Self-Governance, San Fransisco.

Socialist Republic of Vietnam, 2006. 'Prime Minister's Decision No. 81/2006/QĐ-TTg. List of High Priority Projects for Implementation of the National Water Resources Strategy in the Period 2006-2010'.

Tuong, T. P. and Bhuiyan, S. I., 1999. 'Increasing water-use efficiency in rice production: farm-level perspectives', *Agricultural Water Management*, 40(1):117-22.

Zhi, M. 1996. Environmental impact of water-saving irrigation for rice. Irrigation Scheduling: From Theory to Practice. Proceedings of the ICID/FAO Workshop, Food and Agriculture Organisation of the United Nations, Rome.

10.1.1 List of publications produced by project

10.1.2 Research reports

Cheesman, J., Hoc, V. K., Bennett, J. W., and Refsgaard, A., 2008. Welfare from water in the Dak Lak Plateau of Viet Nam: exploring water allocation policy options, Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 7, Canberra.

Cheesman, J., Son, T. V. H. and Bennett, J. W., 2007. Valuing irrigation water in coffee production in Viet Nam's Dak Lak Plateau: a marginal productivity analysis, Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper No. 6, Canberra.

Cheesman, J., Vu, V. D. H., Son, T. V. H. and Bennett, J. W., 2007. Household willingness to pay for irrigation efficiency programs yielding uncertain outcomes in Viet Nam's Dak Lak Plateau, Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 5, Canberra.

Cheesman, J. and Bennett, J. W., 2007. The marginal economic value of water in irrigated rice production in the Dak Lak Plateau, Viet Nam: results from a simulation and optimisation analysis*, Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 4, Canberra.*

Cheesman, J., Son, T. V. H., Thuy, T. D., Vu, V. D. H. and Bennett, J. W., 2007. The marginal economic value of household water in Buon Ma Thuot, Viet Nam, *Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 3,* Canberra

Cheesman, J., 2005. An economic model for optimising agricultural water allocations in Dak Lak, Viet Nam, *Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 2,* Canberra.

Cheesman, J. and Bennett, J. W., 2005. Natural resources, institutions and livelihoods in Dak Lak, Viet Nam, *Managing Groundwater Access in the Central Highlands of Viet Nam Project Research Paper 1*, Canberra.

10.1.3 Journal papers

Cheesman, J. W. and Bennett, J. W., (forthcoming, accepted February 2008). 'Farm size, irrigation infrastructure, and the efficiency of coffee production in Viet Nam revisited', *Forests, Trees, and Livelihoods*, 18(4).

Cheesman, J., Bennett, J. W. and Son, T. V. H., (forthcoming, accepted May 2008). 'Estimating household water demand using revealed and contingent behaviours: evidence from Viet Nam.' *Water Resources Research*, doi:10.1029/2007WR006265.

Cheesman, J., Bennett, J. W. and Son, T. V. H., (revise and resubmit March 2008). 'Willingness to pay for uncertain project benefits: results from a randomised payment card contingent valuation survey', *Environmental and Resource Economics*.

10.1.4 Conference papers

Cheesman, J. and Bennett, J. W. 2006. An integrated approach for modelling the impacts of land and water resource use in the Dak Lak plateau, Viet Nam. 50th Annual Conference of the Agricultural and Resource Economics Society, Sydney, Australia, February 6-8.

Cheesman, J., Son, T. V. H., Thuy, T. D., Vu, V. D. H. and Bennett, J. W. 2007. Demand for household water in Buon Ma Thuot, Viet Nam: evidence from households' revealed and stated preferences. 51st Annual Conference of the Australian Agricultural and Resource Economics Society, Queenstown, New Zealand, February 7-9.

Cheesman, J. and Vu, V. D. H. 2008. Household willingness to pay for irrigation water use efficiency programs yielding uncertain outcomes in the Dak Lak Plateau of Viet Nam: results from a randomised payment card contingent valuation study. Greening Asian Growth - Economic Transition and Sustainable Agricultural Development in East and Southeast Asia, Nanjing, China, October 29-30.