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Final report

Small research and development activity

project

Opportunities to improve the sustainable utilisation and management of water and soil resources for coastal agriculture in Vietnam and Australia

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Acronyms

ASISOV - Agricultural Science Institute for the Southern Central Coast of Vietnam
CMHF - Provincial Centre for Meteorology and Hydrological Forecasting
CWRPI - Centre for Water Resources Planning and Investigation
DARD - Department of Agriculture and Rural Development (provincial)
DONRE - Department of Natural Resources and Environment (provincial)
DWRPIS - Division 8 of CWRPI for South Vietnam
DWRPIC - Division 7 of CWRPI for Central Vietnam
HUAF - Hue University of Agriculture and Forestry
ICD - International Cooperation Department of MARD
IMC - Irrigation Management Companies
IWMI - International Water Management Institute
IWRP - Institute for Water Resources Planning
MARD - Ministry of Agriculture and Rural Development
MU - Murdoch University
MONRE - Ministry of Natural Resources and Environment
MOSTE - Ministry of Science, Technology and Environment (MOSTE)
NCMHF - National Centre for Meteorology and Hydrological Forecasting
NIAPP - National Institute for Agriculture Planning and Projection
NLU - Nong Lam University
NSW DPI - New South Wales Department of Primary Industries
SFRI - Soil and Fertiliser Research Institute
SIWRP - Southern Institute for Water Resources Planning
VAAS - Vietnam Academy of Agricultural Science
VAST - Vietnamese Academy of Science and Technology
VAWR - Vietnam Academy of Water Resources

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2 Executive summary

This SRA follows two previous ACIAR projects in south central coastal Vietnam (SCC VN); SMCN 2003/035 and SMCN 2007/109. Recommendations emerging from both projects highlighted a need to evaluate the sustainability of groundwater utilisation for agriculture in the region. ACIAR commissioned this SRA with the purpose of scoping opportunities for new water, soil and crop management projects in SCC VN.

Objectives

The objectives for this scoping study were to:

- Identify and review available information on catchment scale water resources relevant to SCC VN, including information being generated by existing and proposed projects.
- Identify priority catchment scale and farm scale water and soil management issues in consultation with regional stakeholders in SCC VN.
- Identify appropriate partners, capacity building needs, achievable project objectives, suitable methodologies and design research and development activities for a large ACIAR project which integrates catchment and farm scale soil and water management strategies, to improve profitability of farmers and improve the sustainability of resource use in SCC VN.

Activities

The objectives for this SRA were achieved between November 2012 and May 2013. Consultation meetings were carried out with 19 government agencies research institutions and universities in November 2012 and January 2013. Publications and documents containing information related to water resources were identified, acquired and reviewed. Outcomes from consultations and the information review are synthesised into this report. A second consultation phase was undertaken in SCC VN in March with prospective partners for a preliminary project proposal developed under ACIAR's Soil Management and Crop Nutrient (SMCN) program. The preliminary proposal was approved by ACIAR via in-house review in March 2013. This report has been written as a milestone for the SRA and as background to the full proposal.

Water resources management in SCC VN

Historically, institutional arrangements for water resources management in Vietnam have been complex and fragmented with responsibilities for surface water under the Ministry of Agriculture and Rural Development (MARD) and groundwater under the Ministry of Natural Resources and the Environment (MONRE). However, Vietnam's water sector has entered a transitional phase with recent changes to the Law on Water Resources which places responsibility for all water resources under MONRE.

Key water resource agencies under MARD include:

National Institute for Agricultural Planning and Projection (NIAPP): NIAPP is a national level planning institute headquartered in Hanoi with considerable influence over policy and planning decisions for agricultural landuse in Vietnam.

Vietnam Academy of Water Resources (VAWR): VAWR functions as a national level water resources research institute. VAWR mostly operates out of Hanoi but has offices in the central highlands and southern Vietnam.

Institute for Water Resources Planning (IWRP): IWRP specialises in national level investigation and planning for water resources development with a primary

focus on surface water resources for irrigated agriculture with institutes located in the north and south of Vietnam.

Departments of Agriculture and Rural Development (DARD): DARD is a provincial level agency with the primary role of implementing national policies, strategies and plans pertaining to rural extension and development, agriculture, fisheries, aquaculture, forestry, salt production, irrigation water supply schemes and flood mitigation within their respective province.

Key water resource agencies under MONRE include:

Centre for Water Resources Planning and Investigation (CWRPI): CWRPI is mandated to plan and implement investigations for water resources, especially groundwater resources, across Vietnam. Southern and Central Vietnam CWRPI divisions are known as Division 8 and Division 7, respectively.

National Centre for Hydro-meteorological Forecasting (NCHMF): Primarily responsible for monitoring and forecasting climate and river conditions and for issuing weather and flood warnings. NCHMF conducts climate research and maintains the national monitoring network for climate and river basin and reservoir hydrology.

Department of Natural Resources and Environment (DONRE): DONRE is a provincial agency with the main function of implementing MONRE's national environmental management and protection policies and regulations within their respective province. The DONREs regulate abstraction of groundwater for municipal and industrial purposes through licensing and monitor water quality and groundwater levels, mainly in urban areas.

Water resources knowledge and research in SCC VN

In SCC VN, 90% of surface water released from reservoirs is used to irrigate lowland rice crops. Farmers on coastal sands and in elevated locations not serviced by lowland irrigation schemes, are highly dependant on groundwater for crop production. Irrigators who utilise surface water are well serviced by current intuitional arrangements but there are no instruments or agencies that regulate groundwater abstraction for agriculture or aquaculture or assist groundwater dependant farmers to manage water use efficiency.

Surface water held in reservoirs and irrigation scheme infrastructure are well documented in water plans produced by MARD agencies. Water plans are in place for all SCC VN provinces covering the period from 2012 - 2020. Given MARD's surface water mandate, these plans mostly focus on infrastructure for surface water irrigation schemes. For the five provinces of Quang Nam, Quang Ngai, Binh Dinh, Phu Yen and Khanh Hoa infrastructure upgrades are planned for 802 irrigation systems and construction of 592 irrigation systems to service an additional 161,979 ha crop land and 13,539 ha aquaculture and additional domestic water supply for 387,400 people. MARD has indicated a budget of 140,770 billion VND ($AUD 6.8 billion) to implement the 2012 - 2020 Central Coastal Vietnam water resources infrastructure plan. The 2012 - 2015 budget indicated for the water resources science and technology program is 120 billion VND ($AUD 6 million).

Groundwater resources are mostly documented in groundwater potential maps produced at 1:50,000 and 1:250,000 scale by CWRPI. Maps have been prepared for most SCC VN provinces but to date groundwater exploitation plans for SCC VN have only been prepared for Phu Yen province. Plans for Ninh Thuan and Binh Dinh province are currently under development. The official total exploitable dynamic groundwater reserve for SCC VN is estimated at 4.3 Mm^3/day. However, the accuracy of this estimate is uncertain. A Vietnamese Ministry-level Department of Water Resource report states that <3% of SCC VN groundwater systems have been investigated to a reliable level of detail. This

same report estimates total dynamic reserves for SCC VN at 18.2 Mm^3/day to 34.5 Mm^3/day with a sustainable yield of ~2.4 Mm^3/day. Of this only 0.35 Mm^3/day is based on accurate assessments with the remainder based on less reliable data.

Most component data required for water balance modelling are available for SCC VN but there is a notable absence of reliable data on groundwater extracted for rural household consumption and irrigation. A coarse estimate for total groundwater abstraction in SCC VN is 261.8 Mm^3/year but inspection of the calculations for this estimate revealed critical errors.

The Agricultural Science Institute for the Southern Central Coast of Vietnam (ASISOV) is the principle agricultural research institute for SCC VN. ASISOV has been involved in irrigation and water resource research via previous ACIAR projects but their Vietnamese government research predominantly focuses on evaluating cultivars with tolerance to drought, acidic soil and salinity and production technologies for rice, peanut, green peas, soybeans, taro and cashew.

National government funding has supported the VAWR to undertake irrigation research in Ninh Thuan and Binh Thuan. A project completed by VAWR in 2008 adapted irrigation scheduling and developed low cost pressurised and filtered drip irrigation for dragon fruit in Binh Thuan province and table grapes in Ninh Thuan province. Water requirements for dragon fruit were determined and evaluation of partial rootzone drying (PRD) indicated that application of PRD in periods of low water availability has potential to reduce water consumption for dragon fruit by 40% without a yield penalty. Outcomes from the project led to the development of a Vietnamese standard for irrigation of dragon fruit and table grapes.

VAWR also evaluated small scale water storage techniques to supply water for rural household consumption and irrigation in several drought vulnerable hamlets in Ninh Thuan. The techniques mostly involved collection and piping of groundwater discharged from the base of sand dunes to 20m^3 to 30m^3 capacity storage tanks, some covered with plastic to reduce evaporation. Vietnamese government funding is currently supporting VAWR to undertake research to evaluate irrigation hardware and scheduling for sugarcane crops in Quang Ngai province.

The primary focus for many international donor research projects in SCC VN has been Binh Thuan and Ninh Thuan and more recently, Quang Ngai province. A large proportion of these focus on assessing groundwater for domestic consumption.

The project titled "*Groundwater artificial recharge and salinisation prevention as a drought-fighting measure in central coastal areas of Vietnam*" was completed in 2001 through collaboration between the German government and the Ministry of Sciences, Technology and Environment of Vietnam (MOSTE). The project was located in the Luy River delta of Binh Thuan province. Results from modelling indicated that a recharging trench covering a total area of 1 km^2 could potentially divert an additional 133 m^3/day to 300 m^3/day of water to the local aquifer. Scenario testing for seawater intrusion mitigation indicated that the most effective, but also most expensive, option for preventing further seawater intrusion into the Luy Delta aquifer was to construct an underground slurry dyke system. After installation of the dyke, saline water would be pumped from wells installed near the dyke wall out to sea.

Between 2004 and 2010 a large project titled "*Augmenting groundwater resources by artificial recharge in Binh Thuan province, Viet Nam*" project (IHP, 2011) was completed by a consortium involving: UNESCO, an Italian university and Vietnamese institutes including , Vietnamese Academy of Science and

Technology (VAST), Binh Thuan DARD and DONRE, and CWRPI. Extensive field investigations, hydrogeological and geophysical surveys, installation of monitoring systems and chemical and isotope analyses of groundwater were carried out. Capacity building during the project extended to ~200 Vietnamese participants who gained competency in artificial aquifer recharge, the use of stable isotopes in hydrology and hydrological methods. This project was first to implement an artificial aquifer recharge pilot project in Vietnam. The pilot project was established in the Bau Noi well field with a 5 km pipe installed to supply ~220 m^3/day water to Hong Phong village.

The project titled "*Improvement of groundwater protection in Vietnam - IGPVN*" commenced in 2009 with phase 1 completing in 2010. Phase 2 of this project is ongoing until 2014. The project is funded by the German Ministry for Economic Cooperation. Primary partners for this project are the Institute for Geosciences and Natural Resources (BGR), Germany and CWRPI (DWRPIC-Division 7) with collaborative partners including DONREs from Nam Dinh, Ha Noi, Ha Nam, Soc Trang and Quang Ngai. Phase 1 of the project focused on the central Vietnam province of Nam Dinh. Phase 2 has extended to other parts of central Vietnam and Quang Ngai province in SCC VN. Recommendations to emerge from phase 1 of this project include the following measures to address groundwater overexploitation and salinisation: enforcement of regulation to control extraction; registration and extraction licensing; central water supply based on treated surface water; reducing extraction by identification of sources for groundwater loss or misuse, alternatives for groundwater usage and awareness campaigns; optimizing extraction; conjunctive usage; groundwater monitoring.

Ninh Thuan province has been the subject of recent groundwater salinity surveys under a project co-funded by UNESCO and Vietnamese and Italian governments. The project is titled "Impacts of sea level rise by climate change on coastal zone and Islands in Central Part of Viet Nam" and commenced in 2006. Data collected to date indicates that increasing groundwater salinity in Ninh Thuan is primarily caused by: 1) over extraction, mostly for irrigation, of brackish water from shallow coastal sand dune aquifers; 2) industrial salt production in Ninh Thuan. The situation is expected to worsen and spread further inland.

Previous ACIAR projects in SCC VN (SMCN 2003/035, SMCN 2007/109) are the only known foreign donor projects to have conducted applied on-farm research related to water resources. Field experiments with cashew demonstrated productivity gains from extending the duration of irrigation from the standard practice of flowering only to irrigating from flowering through to nutset. Water savings were achieved in cashew and grapes using drip irrigation. In both Binh Dinh and Ninh Thuan, cashew yields increased significantly with mini-evaporation pan irrigation scheduling. Water use efficiency was improved with mangoes and the volume of water applied to grapes was halved without a yield penalty. Mini-evaporation pan irrigation scheduling resulted in 14% to 49% increases in peanut yields with significant water savings.

While several reviews of water resource policy in Vietnam have been undertaken at a national level, none of these have specifically focused on examining the impacts of water resource policy on communities in SCC VN. A study due to complete in June 2013 titled *"Linking increases in water use efficiency for food production at the farm scale to global projections"* aims to improve policy and instruments available to farmers and policy makers for increasing water use efficiency in agricultural food production. This study is funded by the German Government and being implemented by the Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB), International Food Policy Research Institute (IFPRI) and SIWRP.

This project is mostly focused in Ninh Thuan province and combines a local farm scale approach with a global modelling approach to further develop a methodology for estimating agricultural water flows, costs of production factors that affect them at the farm scale and to improve projections for agricultural water use. The study is based on a methodology for water flow balance at the farm scale using models developed at ATB and IFPRI which simulate both water supply and water demand for food production.

Conclusions

This SRA study has developed a clearer understanding of the water resource information base, its governance and management in Vietnam and identifies research priorities for water, soil and cropping systems in SCC VN.

A key observation to emerge during the SRA was that there are no agencies or groups working with groundwater dependent farmers to assist them in utilising groundwater sustainably. There appears to be an opportunity for technical and policy interventions aimed at facilitating greater interaction between MARD and MONRE agencies and groundwater dependant farmers in SCC VN. This opportunity appears to fit well with ACIAR's Land and Water Resources (LWR) or Agricultural Development Policy (ADP) programs.

Information available on SCC VN water resources discovered during the SRA exceeded expectations. However, the most notable gap in water resource knowledge pertains to an absence of reliable data on groundwater abstraction and sustainable yield. This indicates an opportunity for new ACIAR projects to model this flow. Such knowledge is critical to evaluating the sustainability of groundwater dependent agriculture in SCC VN.

Potential contamination of groundwater is a known issue in a number of rural locations but monitoring is rarely undertaken outside urban areas. There is an opportunity for future ACIAR projects to facilitate greater recognition of the need for groundwater quality monitoring in rural areas. Improved knowledge of groundwater quality would enable targeting of areas where farmers need improved technologies to improve on-farm irrigation and nutrient management.

Seawater intrusion into coastal aquifers in SCC VN has occurred in a number of locations with affected areas totalling 750 km^2. Solutions are needed to improve management of groundwater abstraction to reduce risks of seawater intrusion events and to adapt farming systems to saline irrigation water where intrusion is already present and largely irreversible. A number of international donors are seeking solutions to saline intrusion but none are seeking on-farm solutions. This highlights an opportunity for ACIAR projects.

Constraints associated with the sandy soils of SCC VN contribute toward groundwater sustainability issues. Farmers, especially those who manage high value crops, have a tendency toward excessive irrigation and NPK fertiliser use to compensate for the low water and nutrient holding capacity of the sands. Organic and clay soil amendments can ameliorate these constraints but there is a need to validate the efficacy and profitability of using local organic and clay resources for amendment of sands. Sulfur and micronutrient management is not a feature of current farming systems in SCC VN. SMCN 2007/109 demonstrated significant productivity gains in peanut, cashew and mango from treating sulphur and micro-nutrient deficiencies. However, there remains a need to evaluate cost effective solutions to correcting nutrient deficiencies on sands and to demonstrate these at farm-scale so that approved recommendations and fertiliser products can be developed and extended to farmers.

Developing capacity building programs for famers needs to be given greater attention under future SCC VN ACIAR projects. Future ACIAR projects need to allocate time toward understanding extension approaches in SCC VN and

evaluating current and alternative approaches for effective scale up and scale out of project outcomes. Proving up technologies and initiatives via pilot scale out and field demonstrations are critical to securing central government funds to support scale out beyond the life of an ACIAR project. As such future ACIAR projects should allocate resources to support these.

Opportunities

Opportunities for ACIAR's LWR and ADP programs

- Support projects on policy intervention to improve regulation and funding for services provided to groundwater dependant farmers.

Opportunities for ACIAR's LWR program

- Support landscape scale water balance studies with the purpose of understanding whether current and projected groundwater utilisation for primary production in SCC VN is sustainable.
- Facilitate implementation of coordinated programs for water quality monitoring, modelling and mapping in targeted rural areas within SCC VN.
- Support hydrological and salinity modelling and conduct groundwater and community surveys to determine the status of coastal aquifer salinity in SCC VN districts were data does not exist.
- Improve extension and communication to improve outcomes for groundwater dependant farmers.
- Support groundwater hydrology investigations in central provinces where there are gaps in groundwater resource knowledge.
- Support economic modelling to determine the feasibility of developing irrigation schemes to buffer against water shortages in groundwater dependant areas and improve production and facilitate development of agriculture in areas with limited or no access to water for irrigation.
- Improve prediction of water demand and distribution through modelling and improve communication between surface water users, water resource managers and IMC's.

Opportunities for ACIAR's SMCN program

- Support research to evaluate practical and affordable solutions to improve fertiliser use efficiency and correct nutrient deficiencies in SCC VN sands.
- Support research that evaluates local organic resources and clays as soil amendments to ameliorate site specific soil constraints.
- Support research to develop and adapt integrated nutrient and water use management technologies in SCC VN.
- Support research to adapt irrigation and fertiliser practices and cropping systems to reduce the impact of saline water and soil on farmer livelihoods.
- Implement capacity building activities to support the development, testing and implementation of integrated nutrient and water use management technologies by research and extension personnel and groundwater-dependent farmers.
- Facilitate development of guidelines for production and use of recycled organics in SCCN agriculture.
- Support scale-out programmes through Vietnamese agencies for the above research innovations.

3 Introduction

3.1 Background

ACIAR has identified South Central Coastal Vietnam (SCC VN) as a priority for investment in agricultural research and development. SCC VN extends from Ninh Thuan province in the south to Quang Nam province and Da Nang city in the north (Figure 1). Around 60% to 70%, of an estimated population of 9 million, earn the majority of their income from agriculture and the region is subject to a high incidence of rural poverty.

Average annual rainfall varies from 600 mm along the coastal fringe of the southern province of Ninh Thuan to more than 1,800 mm in the central province of Binh Dinh. The region experiences seasonal rainfall extremes with frequent and severe flooding in the 3 to 5 month wet season and soil water deficits in the 7 to 9 month dry season. Central coastal Vietnam contains ~330,000 ha of sandy soils which mostly occupy upland cropping areas (Hoang et al. 2010). Predominant upland crops are cashew (60,000 ha), mango (12,100 ha), peanut (32,100 ha), cassava (108,900 ha) and vegetables (66,500 ha) (Source: MARD Statistics and Food Security database). Crop productivity is constrained by soil physical limitations and nutrient deficiencies associated with the sands (Phan, 2011a,b,c; Hoang et al. 2010). Irrigation of lowland rice consumes 90 % of stored surface water while irrigated upland and coastal mixed cropping systems are mostly dependent on groundwater for irrigation. Groundwater is also extracted for household use in these areas. Overexploitation of groundwater, leaching of nutrients to groundwater due to excessive fertiliser use and groundwater salinity are problems affecting the sustainability of groundwater-dependent farming systems.

Complementary to Vietnam's national water resource strategies, ACIAR's priorities for SCC VN include development and promotion of sustainable practices to protect water resources. Between 2007 and 2012, ACIAR funded two projects in SCC VN. These were SMCN 2003/035 "Improving the utilisation of water and soil resources for tree crop production in coastal Vietnam and NSW" and SMCN 2007/109 "Sustainable and profitable crop and livestock systems for southern central coastal Vietnam". Recommendations emerging from the external review of these projects highlighted the need to assess the sustainability of groundwater dependent agriculture in SCC VN. Recommendations also highlighted a need to protect groundwater resources from overexploitation, nutrient contamination and salinisation.

Following on from previous projects, ACIAR commissioned the small research activity (SRA) SMCN 2012/017 "Opportunities to improve the sustainable utilisation and management of water and soil resources for coastal agriculture in Vietnam and Australia". The primary aim for this SRA is to scope out opportunities for a large ACIAR project focused on water and soil resource priorities for SCC VN. The following report presents outcomes from a scoping study conducted under this SRA.

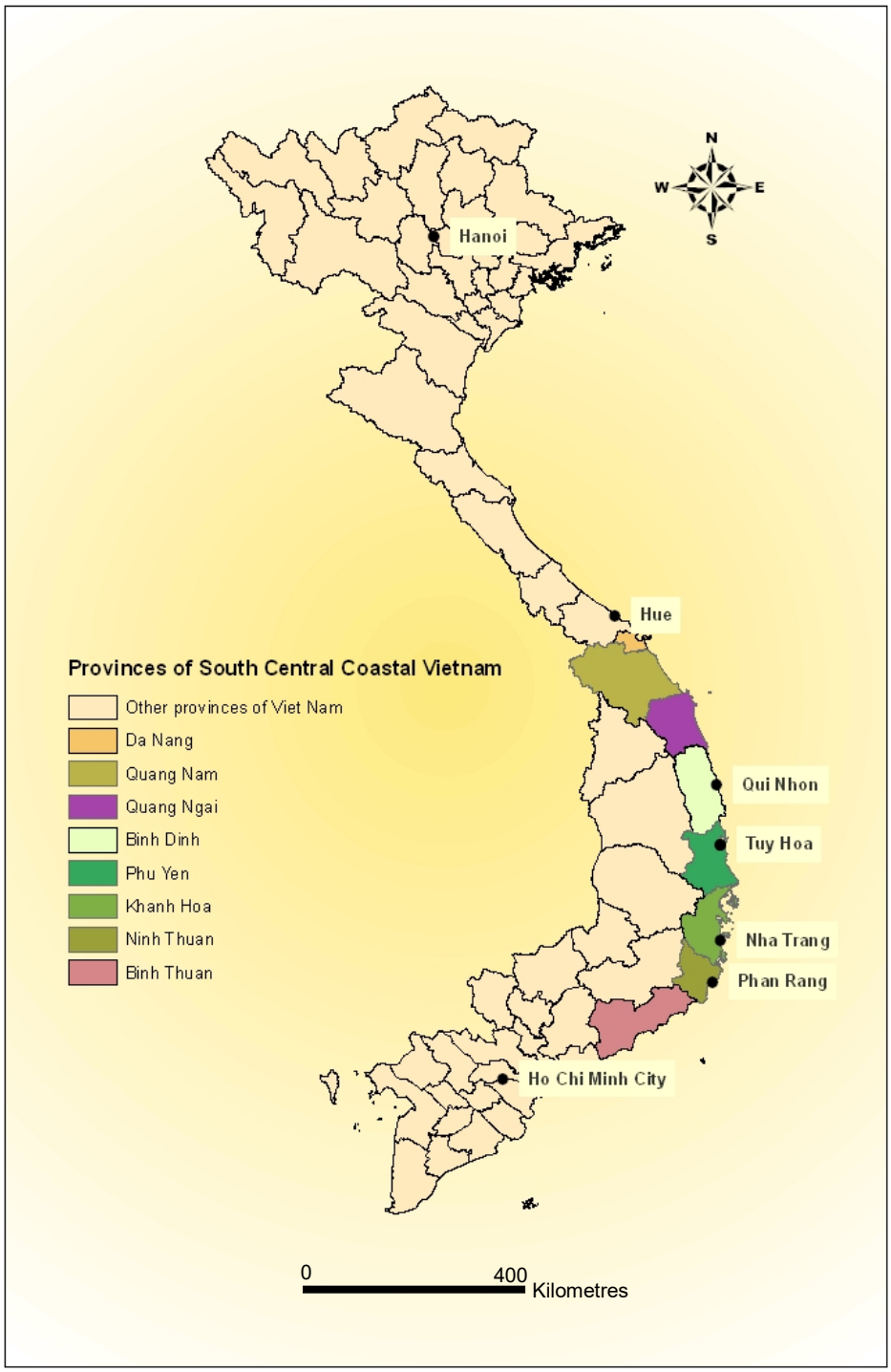

Figure 1. Provinces of South Central Coastal Vietnam (note: Binh Thuan is also officially part of SCC VN; this map defines SCC VN as the coastal provinces under ASISOV's jurisdiction) and locations where consultation meetings were

3.2 Objectives and deliverables

Objectives

This SRA formally commenced 1/11/2012 and completed 30/04/2013. Objectives for the scoping study were as follows:

- Identify and review available information on catchment scale water resources relevant to SCC VN, including information being generated by existing and proposed projects.
- Identify priority catchment scale and farm scale water and soil management issues in consultation with regional stakeholders in SCC VN.
- Identify appropriate partners, capacity building needs, achievable project objectives, suitable methodologies and design research and development activities for a large ACIAR project which integrates catchment and farm scale soil and water management strategies, to improve profitability of farmers and improve the sustainability of resource use in SCC VN.

Deliverables

A final report primarily synthesising outcomes from consultations and a review of water resources information.

A proposal for a large 4-year ACIAR research project which aims to integrate catchment and farm scale soil and water management strategies to improve the sustainability of resource use and farm profitability in SCC VN.

3.3 SRA team

This SRA was led by Dr Peter Slavich (Research Leader) and Dr Brad Keen (Project Officer) of he New South Wales Department of Primary Industries (NSW DPI) and Dr Hoang Minh Tam (Director) of the Agricultural Science Institute for the Southern Central Coast of Vietnam (ASISOV). Collaborators were Prof. Richard Bell of Murdoch University (MU, Australia) and Dr Chu Thai Hoanh from the International Water Management Institute (IWMI).

ACIAR SMCN 2012/017 scoping study team involved in November 2012 consultation tour: (left to right) Dr Chu Thai Hoanh, Dr Brad Keen, Dr Hoang Minh Tam, Mr Nguyen Thai Thinh, Dr Peter Slavich and Mr Nguyen Van Bang.

3.4 Scoping study activities

As the major activity for the scoping study phase of this SRA, consultation meetings were held with key institutional stakeholders in Vietnam. These meetings were undertaken during a visit to Vietnam by NSW DPI and IWMI members of the scoping study team between 11th and 23rd November 2012. Further consultation meetings were undertaken by Prof. Bell (MU) between 22nd January and 1st February 2013.

During the first consultation visit a total of 19 consultation meetings were undertaken with two universities and various government agencies at the national, regional and provincial level in Hanoi, Ho Chi Minh City and in several locations within SCC VN (Figure 1). The majority of these agencies are positioned under the Vietnamese Ministry of Agriculture and Rural Development (MARD) and the Vietnamese Ministry of Natural Resources and Environment (MONRE).

The following details the institutions with which consultation meetings were held.

International Cooperation Department (ICD under MARD) represented by Dr Luong The Phiet (Director) and Mr Nguyen Anh Minh (Head of Bilateral Cooperation Division).

Vietnam Academy of Agricultural Science (VAAS under MARD) represented by Dr Nguyen Van Bo (President) and Ms Bui Huy Hop (Deputy Director).

Institute for Water Resources Planning (IWRP under MARD) represented by Dr Dao Ngoc Tuan (Deputy Director), Mr Bui Quang Tuan, (Vice Chief Division of Science and Technology), Mr Dang Vi Nghiem, (Vice Chief Division of Mid-Central and Central Highland), Mr Phung (Chief of Hydro-Meteorology Division).

Soils and Fertiliser Research Institute (SFRI) (under VAAS under MARD) represented by Dr Tran Duc Toan (Deputy Director), Mr Dung (Soil Research Department), Mr Hung (Science and International Cooperation), Mr Phung (Head of Soil Research Department)

National Institute for Agriculture Planning and Projection (NIAPP under MARD) represented by Dr Nguyen Tuan Anh (vice Director), Mr Vu Cong Lan (Head Division of International Cooperation and Project Management), Mr Lai Ngoc Thanh.

Vietnam Academy of Water Resources (VAWR under MARD) represented by Assoc. Prof. Le Manh Hung (Director General), Assoc. Prof. Nguyen Tung Phong (Deputy Director General), Dr Truong Van Bon (Director Centre for Research for Estuaries and Coastal Engineering).

Hue University of Agriculture and Forestry (HUAF) Faculty of Land Resources and Agricultural Environment represented by Dr Huynh Van Chuong (Dean), Dr Hoang Thi Thai (Researcher), and other researchers.

HUAF Institute of Resources, Environment and Biotechnology represented by Prof. Le Van Thang (Vice Rector) and two other researchers.

Nong Lam University of Agriculture and Forestry represented by Assoc. Prof. Nguyen Hay (Rector), Dr Ngueyn Ngoc Thuy (Head International Cooperation Department), Dr Vo Thai Dan (Dean Agronomy), Dr Le Quoc Tuan (Dean, Environment and Resources), Assoc. Prof. Le Quang Hung (Director, Industrial Crops), Assoc. Prof. Nguyen Kim Loi (Director RC for Climate Change / Applied Geomatics).

Division 8 of Water Resources Planning and Investigation for the South of Vietnam (DWRPIS under MONRE) represented by Dr Bui Tran Vuong (Deputy Director General).

Southern Institute for Water Resources Planning (SIWRP under MARD) represented by Mr Nguyen Xuan Hien (Director), Mr Nguyen Vu Huy (Vice Head of Dong Nai and Ninh Thuan-Binh Thuan Planning Division).

Division 7 of Water Resources Planning and Investigation for Central Vietnam (DWRPIC under MONRE) represented by Dr Ho Minh Tho (Vice Director), Mr Ho Minh

Tho (Vice Director), Mr Nguyen Ton (Head of Technical Office), Mr Vu Manh Hai (Vice Head of Technical Office)

Ninh Thuan Department of Natural Resources and Environment (DONRE-NT under MONRE) represented by Mr Nguyen Tan Tung (Vice Director), Mr Phan Hoang Van (Secretary of Water Board).

Ninh Thuan Department of Agriculture and Rural Development (DARD NT under MARD) represented by Mr Luu Khoan (Vice Director - Agriculture), Mr Nguyen Hong Nhut (DARD), Mr Le Dinh Qui and Mr Nguyen Phu Dien.

Phu Yen Department of Agriculture and Rural Development (DARD-PY under MARD) represented by Mr Bien Minh Tam (Director), Mr Nguyen Van Phuong (Agriculture Office), Mr Pham Quoc Hoang (Agriculture Office).

Binh Dinh Department of Agriculture and Rural Development (DARD-BD under MARD). Dr Ho Ngoc Hung (Vice Director), Mr Pham Van Phat (Crop production), Mr Nguyen Hai Duy Nguyen (International Cooperation)

Binh Dinh Provincial Centre for Meteorology and Hydrological Forecasting (PCMHF under MONRE). Mr Luong Ngoc Luy (Vice Director, Meteorology); Mr Nguyen Ngoc Quynh (Vice Director, Hydrology)

Binh Dinh Department of Natural Resources and Environment (DONRE-BD under MONRE). Mr Dinh Van Tien (Vice Director), Mr Vo Minh Duc (Head of Water Resources and Meteor-Hydro Office), Mr Ho Van Hiep (Office of Water Resources and Meteor-Hydro)

Agricultural Science Institute for the Southern Central Coast of Vietnam (ASISOV under VAAS of MARD). Dr Hoang Minh Tam (Director General), Dr Ho Huy Cuong (Vice Director), Mr Nguyen Thai Thinh (Director for Semi-arid Region).

The International Water Management Institute was contracted to undertake an inventory and review of water resource knowledge relevant to SCC VN. This review has been incorporated into Section 5 of this report (refer to Appendix 2 for working paper).

Priorities, researchable questions, objectives and activities for a new ACIAR project in SCC VN under the SMCN program were negotiated via consultations with ASISOV and nominated country partners between November 2012 and March 2013. A preliminary proposal confirmation meeting was held with country partners on the 7th March 2013. A phase 1 proposal was subsequently submitted to ACIAR for in-house review. The phase 1 proposal was approved by ACIAR 4thApril 2013 with an invitation to develop an approved full proposal by 31 October 2013. This report concludes with a summary of the phase 1 proposal.

4 Water governance in Vietnam

4.1 History of water governance in Vietnam

A brief overview of the history of Vietnam's water resources sector is essential to understanding how the current arrangements for water resource governance came to be. The evolution of the Vietnamese water sector (Figure 2) has been strongly influenced by historical and political events and, more recently, economic reforms. Between 1945 and 1995 water resource management fell under public works related ministries. In 1995 water resources management for irrigated agriculture transitioned to the newly formed (at that time) Ministry of Agriculture and Rural Development (MARD). Water supply (for industry and domestic consumption) and hydropower were placed under the Ministry of Construction and Ministry of Heavy Industry (more recently renamed as the Ministry of Industry and Trade).

Historically, water resource management in Vietnam has focused on exploitation. Concerns for the sustainability of natural resource exploitation began to emerge in 1989 under "Doi Moi" (land reform policy). In 2002, Vietnam's first environmental protection ministry was formed as the Ministry of Natural Resources and Environment (MONRE). With the formation of MONRE, MARD maintained its functions for managing irrigation infrastructure, mostly surface water reservoirs and channel networks for rice production. However, expertise in groundwater investigation and planning migrated from hydro-geology related ministries into MONRE, which brought planning, management, protection and regulation of groundwater resources under MONRE.

On 21st June 2012 the revised Law on Water Resources (LWR) was approved by the national assembly to bring responsibilities for management and protection of water resources at the river basin scale under the control of MONRE. The revised LWR came into effect 1st January 2013. Under the revised LWR, MONRE's two primary functions are: (i) to prepare and implement a master plan for water resources investigations; (ii) to prepare and implement water resource management plans. However, uncertainty over the division of state management functions for water resources persist due to an ongoing power struggle between MARD and MONRE over water resources management. On 30th October 2012 MARD drafted the Law on Irrigation. While still under review, this bill attempts to clarify that irrigation reservoir and channel network infrastructure for agriculture remains a management function of MARD.

Other ministries that may influence or affect agricultural water resources include: Industry and Trade, Health, Science and Technology, Construction, Transport and Finance Planning and Investment.

A more detailed account of the evolution of water resource management in Vietnam is covered in the water resources review working paper attached in Appendix 2.

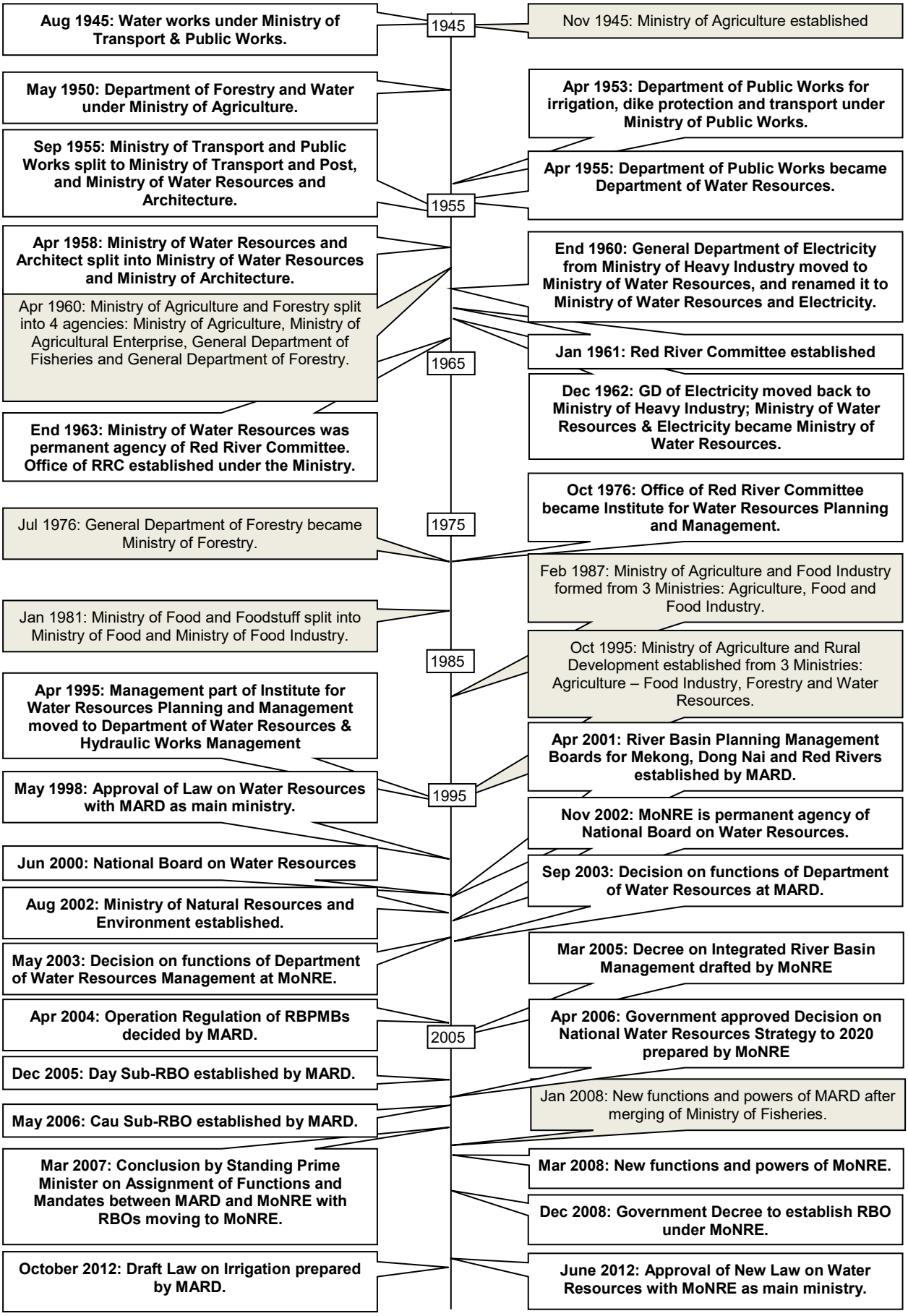

Figure 2. Evolution of water governance in Vietnam. Grey boxes indicate institutional arrangements with indirect relationship to the water sector. (schematic produced by Chu Thai Hoanh).

4.2 Understanding bureaucratic structures in Vietnam

Vietnamese terms for bureaucratic levels and translation of these into equivalent English terms can create confusion about institutional arrangements. For example, the Vietnamese terms "*Cục*", *Vụ*" and "Sở" are qualifiers that indicate the relationship of the particular entity to the ministry. *Vụ*" are ministerial divisions that are responsible for internal administrative duties within a ministry, whereas "*Cục*" are divisions that have responsibilities for implementing state management functions of the ministry. In addition, "Sở" are agencies of a sectoral ministry that operate at a provincial level. The potential for confusion arises when both "*Cục*", *Vụ*" and "Sở" are translated to "department". Add to this sub-departments, divisions, branches and units of the various agencies also being translated to "Department" and it is easy to see how institutional arrangements and power structures in Vietnam's bureaucracy can be readily misunderstood by a person who is more familiar with the hierarchal use of "department" in western bureaucracies.

The Vietnamese term "*Viện*" is translated to "institute" and is applied where the organisation is placed under a ministry but has no state management or ministerial functions, only planning, research and training functions. For example, the Vietnam Academy of Agricultural Sciences (VAAS) is a "*Viện*" with only research and training functions. Institutes under VAAS such as the Soils and Fertiliser Research Institute (SFRI) are also referred to as "*Viện*", even though they are essentially subordinate divisions of VAAS.

Another term that creates confusion in both Vietnamese and in translation to English is "*Trung tâm"* which translates to "Centre". "*Trung tâm"* indicates that the agency has combined or collaborative functions. "*Trung tâm*" can be at a national level directly supervised by the Prime Minister, such as the Centre for Natural Sciences and Technology (CNST). The official English translation for CNST was recently changed to the "Vietnamese Academy of Science and Technology" (VAST) in an attempt to avoid confusion over its functions. The Directors of centres such as VAST have a comparative level of power to their respective Minister. However, "*Trung tâm*" can also be applied to refer to "centres" which are equivalent to "institutes". For example, the "Centre for Water Resources Planning and Investigation", a "*Trung tâm*" under MONRE, is principally a research and planning institute. "*Trung tâm*" can also refer to lower level subordinate divisions within any level of a government agency including a "*Viện*". For example, the Centre for Remote Sensing is a "*Trung tâm*" under the National Institute of Agriculture Planning and Projection (NIAPP) which is a "*Viện*".

The confusion partly arises because the contextual qualifiers in the Vietnamese language are lost when translated to English, thus when Vietnamese terms are translated to the English terms "centre", "academy", "institute" and "department", each may arise at various levels within the Vietnamese bureaucracy. In addition, Vietnam has a large public service. Numerous subordinate agencies have been created under 23 ministries. Each ministry may have as many as 12 deputy ministers. While the functions of subordinate agencies are determined by the ministries, those outside the ministerial offices (e.g. "*Viện*") are often semi-autonomous. For these reasons institutional arrangements can appear fragmented to outsiders, making it difficult to conceptualise and understand bureaucratic structures within traditional organisational charts.

Translation between Vietnamese and English can also create confusion around terms relating to water resources and irrigation. In Vietnamese the literal translation of "*thủy lợi*" is "irrigation", however, when used in the MARD context "*thủy lợi*" is broadly applied to water resources and irrigation. In this context "irrigation" is viewed from a state managed infrastructure perspective. The term "*thủy nông"* is applied when referring to water use for agriculture but is usually translated to "irrigation". For official purposes, the term "*thủy lợi"* is applied to refer to management of surface water resources for irrigation and irrigation scheme infrastructure under MARD and "*tài nguyên nước*" is applied to refer to water resources management (literal translation) under MONRE. MARD has a General

Department of Water Resources (*Tổng Cục Thủy Lợi*; *Tổng Cục* may also be translated as Directorate or General Office) and MONRE has a Department of Water Resources Management (*Cục Quản Lý Tài Nguyên Nước*). In the case of the General Department of Water Resources under MARD and the Department of Water Resources Management under MONRE, both are "*Cục*" which means that they have state management functions. In the Vietnamese language there are distinct differences but when translated to English as departments of "water resources" and "water resources management" the distinctions are less clear.

The key message for this section is that the English title for Vietnamese government agencies does not necessarily indicate their power level or position within Vietnam's bureaucracy. The role of Vietnamese agencies and their position in Vietnam's bureaucracy needs to be understood within the contextual terms of the Vietnamese language which defines their functions.

4.3 Key water resource institutes and functions under MARD

MARD's core responsibilities cover agriculture, forestry, salt production, fisheries, rural water supply and sanitation and rural development. Divisions under MARD with responsibilities associated with water resources are involved in planning and managing water for irrigation and rural households and flood mitigation.

National Institute for Agricultural Planning and Projection (NIAPP)

NIAPP's functions are not specifically focused on water resources but NIAPP has considerable influence over policy and planning decisions for agricultural landuse that are partly based on analysis of water resource availability. As a "*Viện"* NIAPP leads landuse research and planning for rural development in Vietnam. NIAPP's mission is to facilitate the development of rural based industries to reduce poverty, maintain food security and protect the environment. The institute is also involved in planning for resettlement of communities displaced by large infrastructure projects such as hydro-electricity dams.

NIAPP currently employs around 600 personnel with qualifications across a broad range of disciplines, with notable strengths in: investigation, interpretation and consolidation of soil, water resource and climate information and maps; landscape analysis; rural development; spatial information systems. NIAPP have produced land / crop suitability maps for each province in Vietnam.

NIAPP undertook sustainable landuse and land suitability planning projects in SCC VN between 2008 and 2010. These projects were completed in collaboration with the landuse administration division of MONRE and ASISOV. The plans cover the period from 2011 to 2020 and are currently with the Ministries (MONRE and MARD) for approval. NIAPP have also completed: an agro-eco zoning project in 2005; a land use, cropping patterns study for coastal land and semi-arid soils; landuse and irrigation scheme planning for reservoirs in Binh Dinh, Binh Thuan and Ninh Thuan; assessment of fisheries in Binh Dinh province; land resource and land use suitability study for Ninh Thuan province.

Present SCC VN projects managed by NIAPP include: an assessment of desertification and adaptive cropping patterns in Quang Ngai province; mitigating drought impacts by improved water resource management; assessment of salinity and seawater intrusion and adaptive cropping patterns; agricultural landuse solutions for coastal soils in Binh Dinh and Quang Ngai. Intentions for future projects include: identification of land for biofuel crops; planning for crop and water management systems for reducing CO_2eq emissions; planning to increase storage of wet season rain and runoff.

Institute for Water Resources Planning (IWRP)

The Institute for Water Resources Planning (IWRP) is a "*Viện*" specialising in national level research and planning of surface water resources for irrigated agriculture. The principle function of IWRP is to advise the Directorate of Water Resources (a "*Cục*" or ministerial department of MARD) on formulating water resource and flood mitigation planning for rural socioeconomic development across Vietnam. Water resource plans produced by IWRP are approved by MARD. Under IWRP water resource planning integrates infrastructure and water use and allocation planning for hydropower, irrigation, fisheries and urban, industry and rural water supply. Planning under IWRP also encompasses flood and natural disaster mitigation and climate change adaptation.

Within its organisational structure, IWRP has regional sub-institutes for northern, north-central, mid-central, central highlands and southern river basins. However, the Southern Institute for Water Resources Planning (SIWRP) is operated independently to the IWRP. SIWRP responsibilities and activities cover the Mekong Delta, the Dong Nai basin and the SCC VN provinces of Binh Thuan and Ninh Thuan. The national level IWRP employs around 300 personnel. Of these 234 hold engineering degrees. The capabilities of IWRP include economic, hydro-meteorology, water balance and water quality modelling and topographical and geological investigation. The institute operates a basic water testing laboratory, has access to survey equipment and has a high level of capacity in geospatial information systems.

Under its current program, IWRP is working on planning for increasing irrigation capacity in SCC VN by increasing reservoir water storage. There are some 1,200 reservoir projects, mostly for hydropower, planned for the future. As part of the planning process IWRP will carry out impact assessments for water resource infrastructure projects. However, impacts on aquifer recharge are not assessed as part of this. The rationale for not considering impacts on aquifer recharge is that: 1) responsibility for groundwater resources assessment falls under the hydrogeological departments of MONRE; 2) agencies under MARD have a surface water irrigation focus in which aquifer recharge is considered a loss of surface water resources. A water resource plan for Central Vietnam under climate change and sea level rise prepared by IWRP (in Vietnamese language only) was approved and released in October 2012. As an ongoing process IWRP (through regional sub-institutes) aims to update agricultural landuse and water resource spatial data and maps around every 5 years.

Vietnam Academy of Water Resources (VAWR)

The Vietnam Academy of Water Resources (VAWR) is a "*Viện*" that functions as a national level water resources research organisation. VAWR employs around 1,500 personnel, mostly engineers. Donors from at least 40 countries provide financial support directly to VAWR. In addition to the Hanoi based national VAWR office, there are two regional institutes: Southern Institute for Water Resources Research (SIWRR) based in Ho Chi Minh City; Central and Highlands Institute for Water Resources Research based in Da Nang. Fields of research covered by 17 sector specific sub-institutes of VAWR include: water and land resources and environmental protection; engineering for exploitation of rivers, coastal protection and natural disaster prevention; irrigation and drainage; hydropower and hydraulic facilities maintenance and management; technologies for hydropower, aquaculture, agricultural and rural irrigation scheme infrastructure; water resource economics; information and automation technology. The Institute of Water and Environment (IWE) of VAWR undertakes field irrigation and irrigation scheme research. IWE undertook drip irrigation system field research with grapes and Vietnamese apple in Ninh Thuan province between 2008 and 2011.

VAWR is leading a SCC VN groundwater map consolidation project due for completion in 2014. VAWR stated that this project will be one of the most comprehensive groundwater mapping consolidation projects undertaken for SCC VN to date. In addition, VAWR will complete a groundwater modelling study for Quang Nam province in 2013. It is VAWR's

intention to undertake future projects focused on the emerging issues of: climate change and sea level rise; sea water intrusion; on-farm irrigation technologies (e.g. pressurised drip / sprinkler) and irrigation scheduling; water balance modelling and software development for irrigation decision support systems.

Department of Agriculture and Rural Development (DARD)

Each province in Vietnam has a Department of Agriculture and Rural Development (DARD). DARD is a "*Sở*"", meaning that it is a ministerial agency under MARD with functions at the provincial level. DARDs are directed by MARD but administered by Provincial People's Committees. DARDs act as the main conduit between MARD, provincial, district and commune peoples committees and farmers. Their primary role is to facilitate implementation of national policies, strategies and plans pertaining to rural development, agriculture, fisheries, aquaculture, forestry, salt production, irrigation water supply schemes and flood mitigation within their respective province.

With regard to water resources the DARDs play a role in managing irrigation scheme infrastructure up to the commune boundary. Each DARD also maintains extension and information service offices. Extension officers within DARD tend to have expertise oriented toward specific commodities (e.g. rice, annual crops, aquaculture) there are no extension officers that specialise in irrigation or soil management advisory. Sections within DARDs that have responsibilities for irrigation have an irrigation scheme engineering focus, rather than a farmer water use education role. In each province, Irrigation Management Companies (IMCs) are operated under the supervision of provincial people's committees (PPCs) and DARDs to manage headworks and main canals as well as pumping stations, dams and sluices.

4.4 Key water resource institutes and functions under MONRE

As outlined in section 4.1, MONRE was formed in 2002 with the primary function of managing natural resources. Hydrogeology Divisions from other ministries or national general departments were consolidated under MONRE shortly after it was formed. With this consolidation groundwater information and investigative capacity were transferred into MONRE. However, the CWRPI was only established in 2008. At present the process of transferring natural resource management functions from other ministries to MONRE is continuing. The revised Law on Water Resources came into effect 1st January 2013, with MONRE taking on new resource management functions.

Currently, MONRE is responsible for environmental (air, land and water) resource management and protection. Divisions under MONRE are involved in investigating and planning for water resources development and in approval of reservoir construction, water distribution and flood mitigation infrastructure and water exploitation and hydro-meteorological forecasting.

Centre for Water Resources Planning and Investigation (CWRPI)

The Centre for Water Resources Planning and Investigation (CWRPI) is a "*Trung tâm*" under the ministry. CWRPI is mandated to plan and implement investigations for water resources, especially groundwater resources, across Vietnam. CWRPI commenced monitoring and investigation of national groundwater resources in 2008. Under this initiative personnel previously in hydrogeological engineering institutes were moved into CWRPI. CWPRI now operates via a national centre based in Hanoi and semi-autonomous subordinate divisions for southern (Southern CWRPI also known as Division 8) and central (Central CWRPI also known as Division 7) provinces of Vietnam. At present the main function of these subordinate divisions is to undertake exploration, investigation and planning for exploitation of groundwater and mineral resources. The organisation has a high level of capacity in engineering and construction of water supply and wastewater treatment systems, geological survey and monitoring for groundwater resources, spatial

information systems and cartography and specialised research relating to geological and groundwater monitoring and modelling.

The CWPRI Divisions 7 and 8 were recently (2008) involved in a $USD 400,000 Dutch government funded managed aquifer recharge (MAR) pilot project in Ninh Thuan. The particular MAR strategy utilises contour trenches, dug to 1.5 m depth and 800 m length and positioned at 20 m intervals for a total of 1 km. The trenches are intended to capture runoff, allowing time for the runoff water to percolate to the aquifer. Findings from the MAR pilot study indicated that contour trenches diverted an additional 3.6 ML/ha annually to groundwater.

Division 7 are also collaborating with the Institute for Geology and Mineralogy (under VAST) in a UNESCO funded groundwater assessment project for Ninh Thuan. This project is expected to complete by 2014. Division 7 also have ongoing small groundwater survey projects to update 1:50,000 and 1:25,000 scale groundwater potential maps for most provinces in central Vietnam. Groundwater surveys are mostly carried out using temporary mobile equipment, although a few permanent groundwater monitoring stations are installed in Da Nang and Quang Ngai province. The national assembly has allocated 20 billion VND to commence installation of a permanent groundwater monitoring network for provinces from Binh Dinh to Binh Thuan. This program will commence in 2013 and run until 2020 or 2030.

Groundwater survey data is used to prepare groundwater exploitation plans in which general recommendations and guidelines are stated for the total exploitable resource and allocation of groundwater to domestic, industry and agricultural uses. So far only Phu Yen has a groundwater use plan. Division 7 will soon commence preparing plans for Ninh Thuan and Binh Dinh.

National Centre for Hydro-meteorological Forecasting (NCHMF)

The National Centre for Hydro-meteorological Forecasting (NCHMF) is a "*Trung tâm*", an operational unit under the National Hydro-meteorological Service (NHMF), and is primarily responsible for monitoring and forecasting climate and river conditions and for issuing weather and flood warnings. NCHMF responsibilities extend to maintaining a national monitoring network for climate and river basin and reservoir hydrology. Each province has a NCHMF office that operate under divisions for north Vietnam and central and southern Vietnam. The NCHMF are also active in climate research.

Department of Natural Resources and Environment (DONRE)

Similar to the DARDs, each province in Vietnam has a Department of Natural Resources and Environment (DONRE). DONREs are a "*Sở*", or branch department of MONRE. The main function of the DONREs is to facilitate the implementation of MONRE's national environmental management and protection policies and regulations within their respective province.

In relation to water resources DONREs main function is to manage and protect water resources for all exploitation purposes, but at present DONRE mainly focuses on water used for urban domestic and industrial use. This regulatory function is mostly implemented via approving and issuing licenses for larger (>20 m^3 water use /day) single entity water users with licence terms prescribing the maximum volume of water use permitted and pollutant limits for effluent emission.

The DONREs also monitor water quality and groundwater levels. However, human and financial resource allocation to DONREs have been historically variable between provinces and so DONRE's monitoring networks tend to be limited. For example, in Binh Dinh province the DONRE only started monitoring nine wells in 2011. Three of these wells are in the Quy Nhon urban area with the remainder located in six larger urban communes. Only groundwater level and temperature is recorded as the Binh Dinh DONRE do not have adequate budget to monitor water quality. Over the next 2 to 3 years

Binh Dinh DONRE plan to develop a total of 16 monitoring wells with these integrated into an emerging national groundwater monitoring network.

4.5 Overview of water resource management arrangements

Water resources policy in Vietnam is developed at the national level within a national legislative framework. Policy changes typically occur in response to raising of issues on a public agenda. The Law on Water Resources (LWR 08/1996/QH10), Decree 179/1999/ND-CP and, more recently, the 2012 revised Law on Water Resources and Decree 21/2013/ND-CP provide the primary legislative framework for water resource management in Vietnam. A complexity of sub-law and secondary legislation with implications for water resource management has also been created within the different ministries. Sub-ordinate divisions typically adopt legislation pertaining to their respective ministry and functions. A number of reviews (Hirsch et al. 2005; Kellogg and Brown 2009; Can Tho University 2011) have commented on overlaps, duplication and gaps within the legal framework leading to contradictions and conflict between government agencies responsible for implementing water resources law.

Water resource planning and research for agriculture and aquaculture predominantly occurs at a national level and through subordinate national and regional divisions under MARD and MONRE (Figures 4 and 5). The key national and regional institutions and their functions were described above. However, these arrangements are in a transitionary period under the revised Law on Water Resources (21st June 2012), delegating functions for planning and management of water resources at a river basin level to MONRE. The implications of these changes remain unclear and may be complicated further by the draft “Law on Irrigation”, recently introduced by MARD for public comment.

Under existing arrangements, the physical supply of surface water for agriculture, forestry and aquaculture in the provinces of SCC VN (Figure 3) is initially controlled by Irrigation Management Companies (IMC). IMCs are either solely state owned or private-public partnership entities that operate and maintain irrigation reservoir and headwater distribution infrastructure. IMCs are supervised by Provincial and District People’s Committees and are advised by DARDs and DONREs. With water user fees abolished in 2007 IMCs are heavily subsidised by national and provincial governments.

Water Boards operate as committees under PPCs. Not all provinces have Water Boards because the Law on Water Resources does not require each province to form a Water Board. For example, Ninh Thuan province has a Water Board but Binh Dinh province does not. Positions on the Water Boards are filled with representation from the PPC (e.g. vice chairman of Ninh Thuan PPC is also chairman for the Ninh Thuan Water Board), DARD, DONRE and the IMC. One of the Water Board’s primary purposes is to determine water supply requirements and allocation to districts within the province.

River Basin Organisations (RBOs) are also established at different levels; international river, inter-province basin and provincial basin. RBOs were originally established under MARD but Decree 120/2008/ND-CP transferred RBOs to MONRE in 2008. Inter-provincial RBOs engage in participatory management of inter-province catchment issues with representation from each province within a catchment. However, the process of establishing RBOs has been slow, and they have only been established in a few basins, mostly in the north and south of Vietnam.

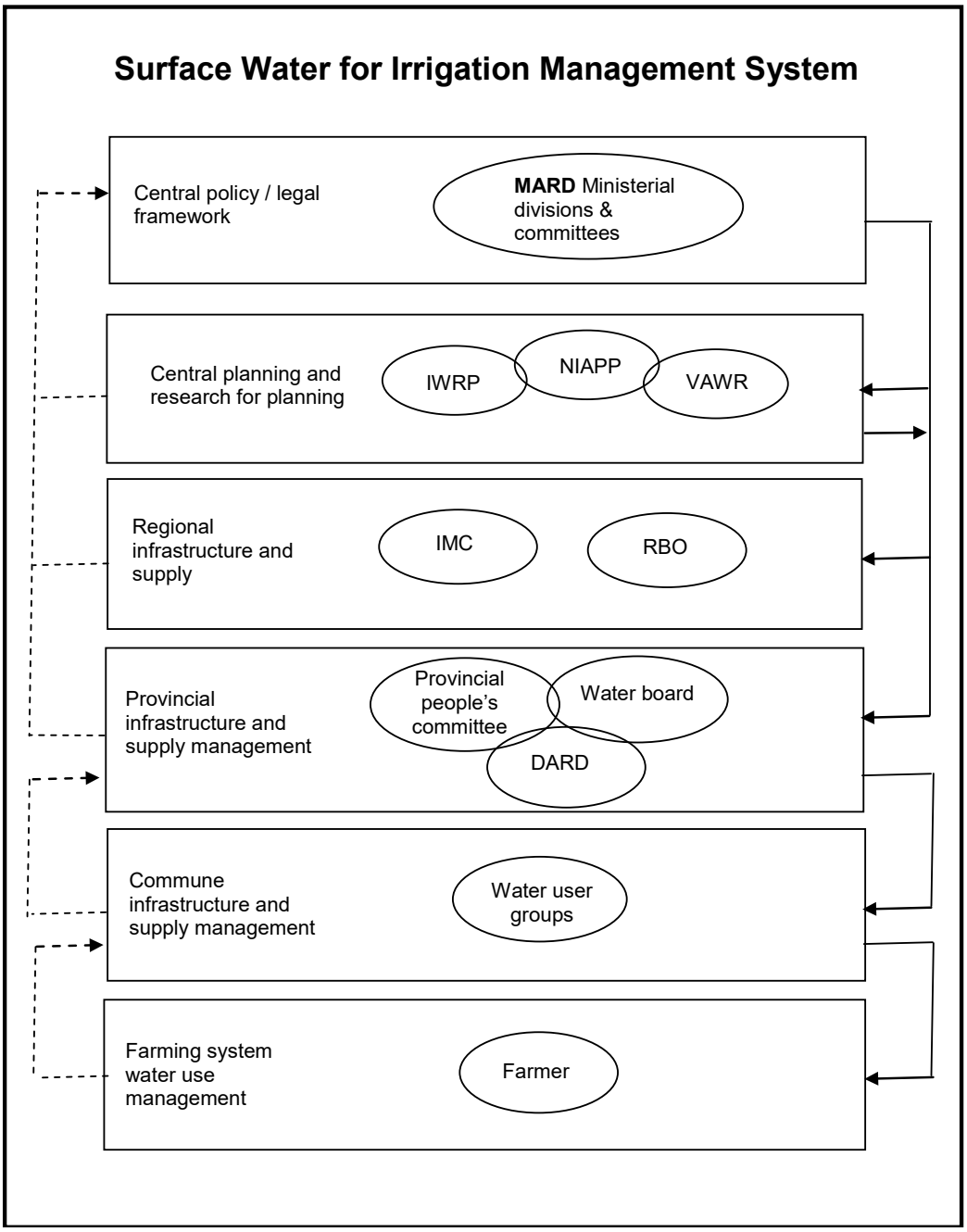

Figure 3. Simplified schematic of the primary components of the surface water supply for irrigation management system as relevant to SCC VN. Solid lines indicate principle pathways of influence and dashed lines indicate feedback pathways.

IMCs release reservoir water into rivers and the irrigation channel system, and they are also responsible for controlling distribution to communes on the irrigation channel network. IMC and DARD responsibilities extend to maintaining irrigation channel infrastructure within the province up to the commune boundary. Beyond the commune boundary farmer water user groups are responsible for maintaining, mostly at their own cost, irrigation water distribution systems (channels and pumps). Water user groups also decide how irrigation water is allocated within the commune. Not all communes have a water user group and those that do predominantly grow lowland rice. Water user groups have not been established in groundwater dependent areas.

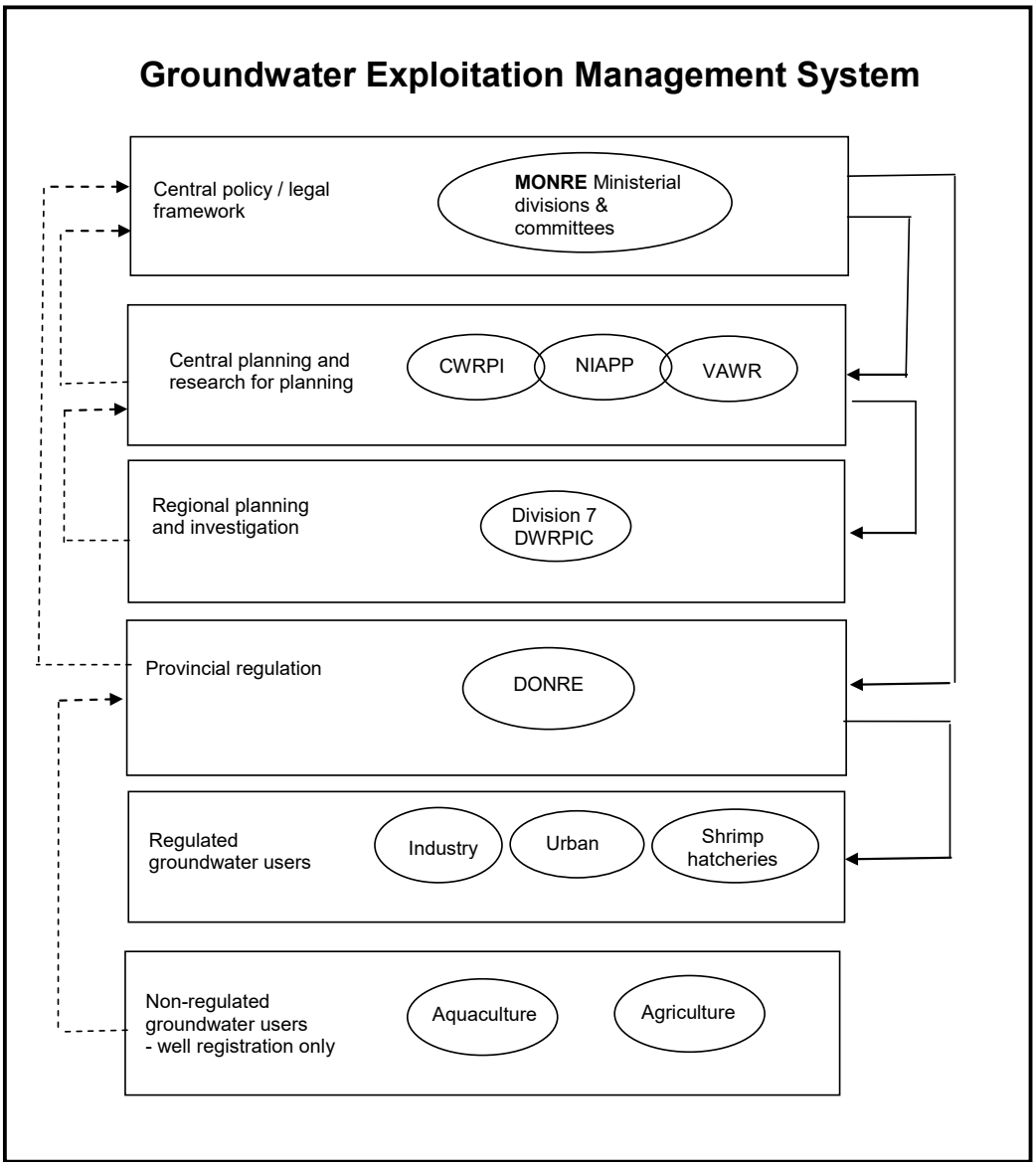

Figure 4. Simplified schematic of the primary components of the groundwater exploitation management system as relevant to SCC VN. Solid lines indicate principle pathways of influence and dashed lines indicate feedback pathways.

Farmers in SCC VN engaged in production of upland crops have a high dependency on groundwater for irrigation. Despite DARD having responsibilities for agricultural resources, groundwater is not a focus for their activities. Implementation of groundwater management falls under the DONRE (Figure 4). However, DONRE do not regulate or work directly with groundwater dependent farmers. Licences are not required by farmers (crop, livestock, forestry and aquaculture) to extract groundwater but farmers are required to register their wells. In reality few farmers register their wells, unless they have accessed government subsidies for well construction, and DONRE does not monitor groundwater extracted for agriculture.

The aquaculture industry is also a significant user of location specific groundwater resources. Estimates for water use by aquaculture range between 20,000 m^3/ha per year (CRP and World Bank 2003) and 35,000 m^3/ha per year (Verdegem and Bosma 2009). Water use by shrimp farmers increases significantly in the dry season when accelerated evaporation from shrimp ponds requires input of fresh water to offset increased salt concentration. DONRE regulate shrimp hatchery companies via licensing but the law does not require licenses for individual shrimp farmers. Consequently, no organisation regulates or monitors groundwater extraction by shrimp farmers.

Under these arrangements it is apparent that systems for managing water resources for irrigated agriculture are surface water and supply focused; almost solely established to support lowland rice production (rice irrigation consumes 90% of stored surface water; pers com. Dao Ngoc Tuan, IWRP). Irrigation water supply and planning for groundwater exploitation dominates institutional arrangements with virtually no organisation working to assist farmers in managing on-farm water use efficiency. Other than through landuse planning, few if any of the institutional arrangements for water resource management service upland crops, especially those dependent on groundwater for irrigation. This highlights a significant gap in water resource management in Vietnam.

5 SCC VN water resources knowledge

Water resources information in SCC VN is collected with the primary purpose of preparing water resource development and management plans. Water resource information is contained within a limited number of sources. The accuracy of information contained within various reports can be unreliable and so only documents approved by a minister or PPC, or prepared by an agency with ministerial functions, are accepted as official reference material in Vietnam. Most of this material is in the form of water resource plans which are written in Vietnamese language only. Chu Thai Hoanh of IWMI interpreted and reviewed these plans for this SRA. This section provides a summary of key information from the full review which is provided in Appendix 2.

5.1 Water resource development plans

Current water resource plans for SCC VN were prepared by IWRP (MARD) for northern provinces of SCC VN. Water resource plans for the southern provinces of SCC VN were prepared by the southern division of CWRPI (Division 8 - MONRE). The split in responsibility for preparing these plans was related to the geographical remoteness of IWRP and Division 8 from their respective base locations in Hanoi and HCMC to SCC VN. Each water resource development plan is produced to align with and inform regional and provincial agricultural development planning under NIAPP (or other agricultural institutes under MARD). Plans are approved by the ministry and signed by the Prime Minister and those parts of the plan that have been approved are formalised via “Decision” documents issued by the ministry.

Water resource development plans are developed at three levels:

1) Regional water resources plan: the IWRP plan covers central Vietnam and includes SCC VN provinces from Da Nang city south to Khanh Hoa; the CWRPI (Division 8) plan covers Ninh Thuan and Binh Thuan provinces.

2) River basin water resource plans: prepared by IWRP or SIWRP; these cover interprovincial basins for rivers that flow from or into SCC VN.

3) Provincial water resources plans: prepared by IWRP or SIWRP or other water resource institutes contracted by the PPC; the main purpose of these plans is to support investment decisions for the respective province.

The Central Vietnam regional plan prepared by IWRP describes the biophysical, landuse and socio-economic setting in Central Vietnam. The area of SCC VN covered by the plan (excludes Ninh Thuan and Binh Thuan provinces) includes 2,232,363 ha of land used for agriculture (67.3 % of the total area). Of this 219,811 ha (6.6 % of total area) is used for rice, 230,541 ha (6.9 % of total area) for other annual crops, 137,499 ha (4.1 % of total area) for perennial crops, 1,620,152 ha for forestry, 15,769 ha for aquaculture and 4,942 ha for pasture.

The IWRP 2012 to 2020 regional water resource development plan for central Vietnam is principally water resource infrastructure focused and outlines priorities and water resource development targets. The plan was approved by the Prime Minister on 24th October 2012 by way of Decision 1588/QD-TTg.

The following general measures are approved under Decision 1588/QD-TTg:

- Repair and improvement of existing reservoirs, especially small and medium sized reservoirs.
- Improve water distribution structures: lining and modernising existing works.

- Constructing and completing large multi-purpose water storage and distribution systems; including water supply to industrial zones.
- Strengthening river and coastal dykes; maintaining and developing flood mitigation works to prevent inundation of main population centres; flood control and adaptation to protect crops from high peak flood events.
- Continuing studies of: multi-purpose mainstream and estuary infrastructure; multi-reservoir operation in all river basins for multi-purpose use in both flood and low-flow periods.

For the five provinces of Quang Nam (including Da Nang city) Quang Ngai, Binh Dinh, Phu Yen and Khanh Hoa, Decision 1588/QD-TTg approves infrastructure upgrades to 802 irrigation systems and construction of 592 irrigation systems to service an additional 161,979 ha crop land and 13,539 ha aquaculture and additional domestic water supply for 387,400 people. The plan indicates a budget of 27,731 billion VND ($AUD 1.4 billion) for irrigation infrastructure construction.

In addition Decision1588/QD-TTg also proposes a number of non-infrastructure measures including:

- Coordination of multi-reservoir operations.
- Forest protection and reforestation at upper catchment areas, strengthening protection forests along the coast and growing trees for protection of coastal dikes.
- Improving efficiency in management and operation of irrigation systems.
- Strengthening the management of plan implementation, checking and enlarging cross-sections of bridges to ensure flood drainage, in particular along national highway 1A, the north-south railroad and the Ho Chi Minh highway.
- Establishment of water management monitoring systems including reservoir supervision systems, with priority given to assessment of infrastructure safety.
- Identifying and resettling communities affected by frequent deep floods and flash flooding and improve flood forecasting and early warning systems.
- Develop a science and technology program for Central Vietnam with focus on climate change and sea level rise covering topics such as drought, river bank erosion and salinity intrusion into estuaries.
- Public education for climate change awareness and to improve capacity of local people to adapt to climate change.

Decision 1588/QD-TTg indicates an estimated total budget of 140,770 billion VND ($AUD 6.8 billion) to implement the 2012-2020 Central Coastal Vietnam water resources plan. Projected budgets for 2012-2015, 2016-2020, 2021-2050 are 24,900, 27,410 and 88,460 billion VND, respectively. However, a detailed breakdown of how the budget is to be allocated is not provided. The 2012-2015 budget for the water resources science and technology program is 120 billion VND ($AUD 6 million). Sources of funding are from the annual budgets of central and provincial governments, government bonds, overseas development aid, program for climate change adaptation, contribution from beneficiaries in the region and other legal funding sources.

More specific detail for how the regional water resource plans will be implemented are contained within river basin and provincial plans. Provincial DARDs and DONRE prepare implementation plans on a zone by zone project basis for investment periods covering subsequent decades (i.e. to 2020, 2030, etc.) aligned with the period covered by the Water Resource Plans.

5.2 Surface water

Information in IWRP River Basin and Provincial Water Resource Plans provide a biophysical description for each basin, maps showing an inventory of reservoir, irrigation scheme, water supply and flood mitigation infrastructure and a recommended action plan for the period covered by the plan. Plans are approved by the ministry (MARD for IWRP plans) and signed by the Prime Minister. Those parts of the plan that have been approved are formalised via “Decision” documents issued by the ministry (e.g. Decision 02/QD-BNN-TCTL "River Basin Water Resources Plan for the Con – Ha Thanh - La Tinh rivers”). The following summarises key information for each basin in SCC VN.

Da Nang city and Quang Nam province (Figure 5)**:** Vu Gia-Thu Bon river basins originate from a maximum elevation of 2,490 m in the highland province of Kon Tum. Rainfall averages 4,000 mm in the upper catchment to 2,000 mm in the lower catchment (ICEM, 2008).

Storage capacity of major multi-purpose reservoirs: Song Tranh 2 521 Mm^3; Tan An 175 Mm^3; Song Bung 2 74 Mm^3; Song Bung 4 322 Mm^3; Dak Mi 1 93 Mm^3 Dak Mi 4 158 Mm^3; A Vuong 267 Mm^3; Song Tranh 521 Mm^3 (ICEM, 2008).

Plans and targets for irrigation, water supply drainage and flood mitigation:

- Develop medium and small reservoirs and the Phu Ninh canal system to supply irrigation water to: 11,632 ha crop land, 2,999 ha aquaculture and supply 199,000 m^3/day for domestic use.
- Improve and repair 39 reservoirs, 11 diversion weirs, 25 pumping stations and 1 canal system servicing 8,905 ha crop land and 3,763 ha aquaculture.
- A total of 155 projects to construct irrigation scheme infrastructure to service 24,088 ha crop land and supply domestic water to 240,500 people.
- Ongoing maintenance and dredging of canal systems and construction of new pumping stations for urban areas.
- Clean and dredge flood mitigation drains and improve coastal dykes to reduce flood risks.

Quang Ngai province: Tra Bong-Tra Khuc-Ve river basins originate in Kon Tum and Quang Nam provinces at a maximum elevation of 2,299 m and run through Quang Ngai province. Rainfall averages 2,400 mm per year in Quang Ngai province with 3,600 mm in the upper catchments (Phan, 2012).

Storage capacity of major multi-purpose reservoirs: Nuoc Trong 300 Mm^3; Dak Drink 1 205 Mm^3; Upper Kon Tum 123 Mm^3; retaining dam in Tra Khuc river for salinity control and water storage for Quang Ngai city.

Plans and targets for irrigation, water supply drainage and flood mitigation:

- Develop medium and small reservoirs and the Phu Ninh canal system to supply irrigation water to: 11,632 ha crop land, 2,999 ha aquaculture and supply 199,000 m^3/day for domestic use.
- Improve and repair 195 irrigation systems servicing 3,792 ha crop land.
- A total of 216 construction projects to develop irrigation scheme infrastructure to service 13,299 ha crop land, 90 ha aquaculture and supply domestic water to 108,000 people.
- Ongoing maintenance and dredging of canal systems and construction of new pumping stations for depression areas and adjustment of the Thoa river channel.
- Clean and dredge flood mitigation drains to improve coastal dykes to reduce flood risks.

- Improve coastal dykes to reduce flood risks.

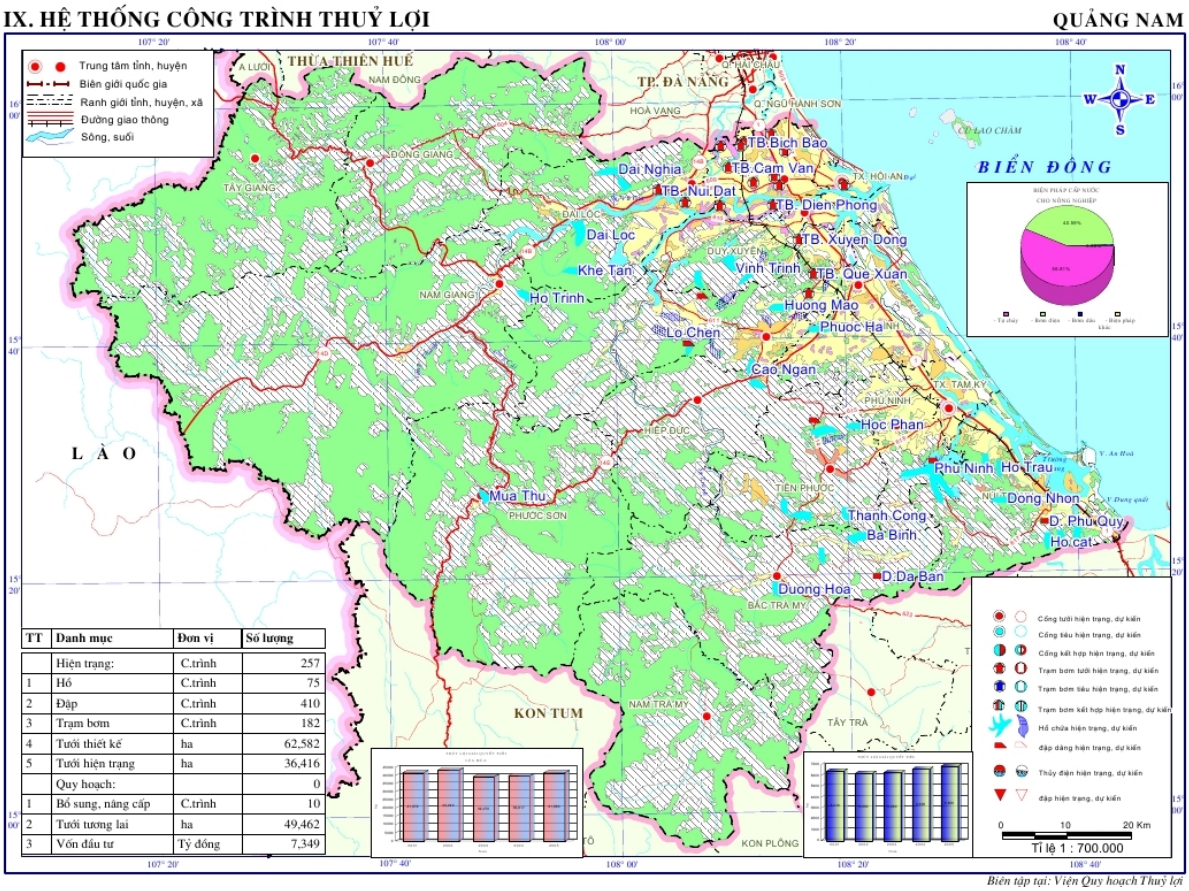

Figure 5: Example of a water system control map for Quang Nam province

Binh Dinh province: The La Tinh river basin originates in Quang Ngai and central Binh Dinh and discharges into the sea near Hoai Huong in the north of Binh Dinh. The Con (also spelt Kone) river is the largest river in Binh Dinh. It originates from Ngoc Roo mountain at a maximum elevation of 925 m near the border with Kon Tum, Gia Lai and Quang Ngai and runs nearly the full length of Binh Dinh to form a delta that discharges into Quy Nhon Bay, 12 km to the north of Quy Nhon city. The Ha Thanh river basin originates in the far south-west of Binh Dinh and forms part of the delta flowing into Quy Nhon Bay. Rainfall across Binh Dinh averages 1,800 mm with 2,400 mm in mountainous areas and 1,500 mm on the coast.

Storage capacity of major multi-purpose reservoirs: Vinh Son 90 Mm^3; Dinh Binh 209 Mm^3; Ka Nak-An Khe 285.5 Mm^3

Plans and targets for irrigation, water supply drainage and flood mitigation:

- Construct 35 new reservoirs, 10 diversion weirs, 12 pumping stations and 3 irrigation canal systems to service 28,533 ha crop land, 951 ha aquaculture and supply water for domestic consumption to 23,900 people
- Improve and repair 352 irrigation systems servicing 18,712 ha crop land and 578 ha aquaculture
- Construct Don Mit - 30 Mm^3 and Dinh Hinh - 112 Mm^3 flood control reservoirs.
- Ongoing maintenance and dredging of canal systems in Dap Da, Tan An and Ha Thanh.

Phu Yen province: At 13,900 km^2 the Ba river basin (Da Rang river) is the largest river basin in central Vietnam. It originates at an elevation of 1,200 m near the south-eastern border of Kon Tum province and flows 388 km through Gia Lai and Phu Yen provinces to enter the south China sea at Tuy Hoa, Phu Yen's capital. Around half of Gia Lai province drains into the Ba River catchment. Annual rainfall within the catchment averages 3,000 mm at the head waters and 1,500 mm on the coast.

Storage capacity of major multi-purpose reservoirs: Lower Ayun 201 Mm^3, Krong Hang 108.5 Mm^3, Song Hinh 323 Mm^3, Lower Song Ba 165.9 Mm^3.

Plans and targets for irrigation, water supply drainage and flood mitigation:

- Complete 95 new irrigation infrastructure projects to service 24,593 ha crop land and 210 ha aquaculture
- Improve and repair 97 irrigation systems servicing 14,925 ha crop land and 1,374 ha aquaculture
- Complete construction of dyke to protect Tuy Hoa city from flood
- Clean and dredge flood mitigation drains to reduce flood risks

Khanh Hoa province: the Cai Ninh Hoa river basin lies to the north of the province and originates near the border with Phu Yen province. The Cai Nha Trang river basin is the major river basin of Khanh Hoa. It originates from an elevation of 2,051 m (Vong Phu Mountain) on the border with Dak Lak province, running through the centre of the Khanh Hoa province to enter the south China sea, near the city of Nha Trang. Rainfall averages 2,000 mm in the upper catchments and 1,300 mm near the coast. The only large lowland area for agriculture is surrounding Ninh Hoa town to the north of the province. Consequently, with only 16.7% (87,100 ha) of total land area used for agriculture, Khanh Hoa has the lowest share of agricultural land in SCC VN.

Storage capacity of major multi-purpose reservoirs: Cai Nha Trang River: Suoi Dau 29 Mm^3, Song Cho 86.9 Mm^3; Cai Ninh Hoa River: Da Ban 201 Mm^3, Ea Krongrou 25.5 Mm^3.

Plans and targets for irrigation, water supply drainage and flood mitigation:

- Continue study of Vinh Phuong dam in Cai Nha Trang for salinity control and water supply to Nha Trang city.
- Implement 63 new irrigation infrastructure projects servicing 26,465 ha crop land, 1,150 ha aquaculture
- Improve and repair 117 irrigation systems servicing 6,106 ha crop land and 451 ha aquaculture.
- Improve coastal dykes and clean and dredge flood mitigation drains to reduce flood risks.

Ninh Thuan province: The water resource development plan for Ninh Thuan province was prepared by Division 8. With Division 8's focus more on groundwater the information for surface water is presented differently to that of the IWRP plans. The priorities are also more reflective of MONRE's functions and groundwater mandate

The Cai Phan Rang River (also known as Dinh River) forms the major river basin in Ninh Thuan. The northwest branch of the river begins from an elevation of 1,600 m in Khanh Hoa and Lam Dong provinces. The main west-east branch originates on the western border with Lam Dong Province, just below the Da Nhim hydroelectricity reservoir. Annual rainfall averages 1,800 mm in the upper catchments to 585 mm on the coast. On average 2.5 billion m^3 water flows into the Dinh River annually. Around 0.5 billion m^3 of this is diverted from the Da Nhim reservoir (built for hydroelectricity production and to supply irrigation water downstream) which is equivalent to the volume of water extracted from the river in 2005. In the lower Cai Phan Rang catchment, the Nha Tring and Cai reservoirs will

supply 13,000 m^3/day fresh water to the Ninh Thuan 1 nuclear power facility which is scheduled for commissioning 2020 (Nuclear Energy International, 2010).

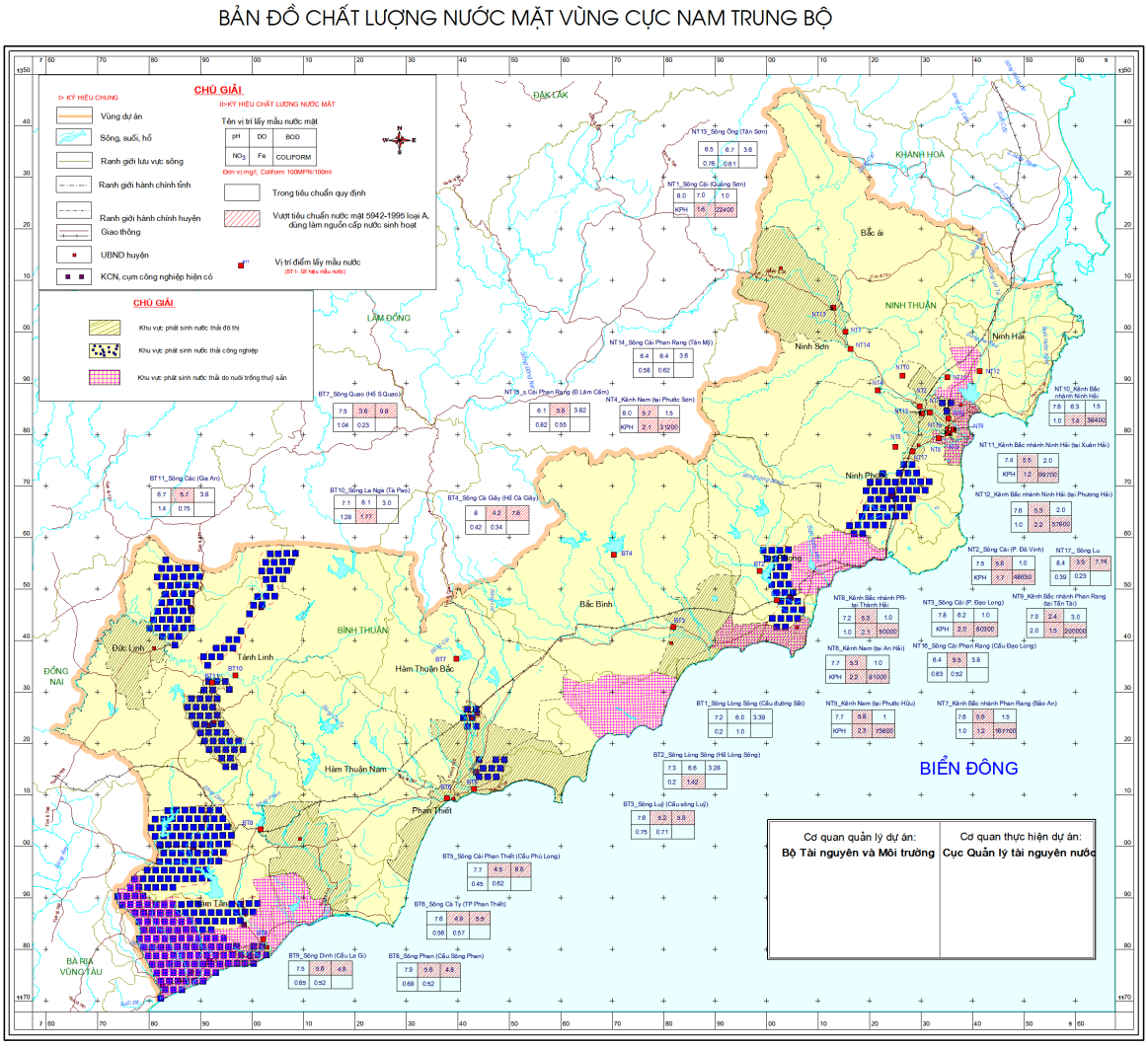

Figure 6. Surface water quality map for Ninh Thaun Province.

Binh Thuan province: The water resource development plan for Binh Thuan province was prepared by Division 8. Binh Thuan has several rivers mostly originating within the province or in the highlands of neighbouring Lam Dong province. The major rivers are the Long Song, Luy, Cai Phan Thiet, Ca Ty, Phan, Dinh (Ham Tan) and La Nga with a total surface water volume of 5.4 billion m^3/year. With the exception of La Nga river, which is a branch of the large Dong Nai river, other rivers in Binh Thuan are short and have limited water volume. The water security strategy for Binh Thuan is principally to divert water from Lam Dong and Dong Nai provinces into the rivers in Binh Thuan. For example, a total of 148 million m^3/year is diverted from the Luy and La Nga rivers, to the Cai Phan Thiet river and 48 million m^3/year is diverted from this river to the Ca Ty river. Under the water resource plan for Binh Thuan provision is made for future infrastructure development to divert 467 million m^3/year from the Dai Ninh reservoir in Lam Dong province to the Luy river and 18 million m^3/year from the Dinh river to the Phan river.

5.3 Groundwater

The IWRP water resource plan provides a general description of aquifers and groundwater resources for Central Vietnam, within the context of water supply for domestic and industrial purposes, but does not discuss groundwater within the context of irrigated agriculture. This contrasts with the Division 8 regional water resource plan which provides more in-depth coverage of the hydrogeology of Ninh Thuan and Binh Thuan provinces as a resource for domestic, industrial and agricultural purposes. Water resource plan “Decisions” under MARD do not mention groundwater, only detailing measures for surface water infrastructure.

Where information on groundwater is provided in the water resource plans, it is presented as a description of the exploitable groundwater inventory. Groundwater quality and use is presented in the context of domestic and industrial consumption to service population centres. Issues with regard to sustainable groundwater utilisation are given cursory mention but water shortage risks and groundwater quality problems are not detailed for specific locations away from population centres.

In addition to water resource plans, groundwater information is also available from 1:50,000 and 1:200,000 scale maps prepared by Division 7 for most SCC VN provinces. The maps display information on the exploitable quantity of groundwater and limited basic water quality data. Data presented in the maps was collected from permanent groundwater stations at Da Nang and Quang Ngai and from temporary monitoring stations in other provinces. At the time of writing Division 7 reported that they are currently updating groundwater maps for Da Nang to Quang Ngai and will soon complete an update of the Phu Yen province water resource plan and begin preparing plans for Ninh Thuan and Binh Dinh.

Aquifers of SCC VN

Holocence sediments are abundant throughout SCC VN and are composed of unconsolidated sand, sandy clay and clay mixed with gravel. The associated pore water aquifers provide a plentiful source of water overall but the volume varies by location with the depth and thickness of the aquifers typically ranging from 2 m upstream to 40 m downstream. Holocene aquifers occur over a large area of lowland Ninh Thuan. These aquifers occur as fresh water lenses associated with river-swamp, marine, marine-wind and river-marine-swamp sediments. Location specific water volume is medium in coarse riverine and marine sediments. In other sediments, location specific water volume tends to be low to very low. Potential discharge is less than 2 m^3/hour from fine sandy sediments and 10 m^3/hour in coarse sediments. The water table fluctuates seasonally, typically ranging from 0.5 m to 4 m. Recharge is predominately from rainwater and flood water infiltration. The aquifers are vulnerable to sea water intrusion in coastal areas and adjacent to estuaries.

Pleistocene pore water aquifers are exposed near the delta border of southwest Thang Binh and Duy Xuyen districts of Quang Nam province and along the terraces of Yen and Qua Giang rivers in Da Nang. In other areas the Pleistocene aquifers are mostly covered by Holocene sediments. Pleistocene and Holocene sediments are composed of similar unconsolidated materials and so the associated aquifers are generally viewed as a single unit. These aquifers are associated with sand and clay soils and gravel and have a thickness ranging from 10 m to 38 m. The Pleistocence-Holcene aquifers are of most significance to the Phan Rang plains in Ninh Thuan province and Phan Thiet and Ham Tan plains in Binh Thuan province. Total groundwater potential estimates for these aquifers is 563,300 m^3/day.The water table fluctuates from 0.2 m to 5 m in low lying areas and 35 m to 45 m at higher elevation. Seeps occur at the base of sand dunes where groundwater fed streams occur. These seeps have a discharge rate of 1 to 2 m^3/hour. Discharge rates measured at bore wells range from 20 m^3/hour to 70 m^3/hour. Recharge is predominately from rain and flood water infiltration.

Pore water aquifers occurring in Neogene sediments are exposed in small areas along the Luy River in Binh Thuan and south of Ma Viet mountain in Ninh Thuan. The remainder are covered by Quaternary sediments. In exposed areas the water table varies from 0.8 m to 4.7 m and the aquifer thickness is 10 m to 20 m. Potential discharge from bore wells is between 1 m^3/hour to 3 m^3/hour. The aquifer is recharged from upper aquifers and surface water percolation. Overall water volume is limited but is used for household consumption in small population centres.

Ai Nghia cleft aquifers occur within Neogene rock formations. Hydrologic pressure maintains the water table at 3 to 5 m below the ground surface. The exploitable volumetric water content is low to medium with recharge mainly by percolation from upper aquifers. Coastal aquifers are usually saline.

The volumetric water content of the Proterozoi, Mesozoi, Paleozoi rock unit cleft aquifers are generally low to medium depending on crack and cavern sizes within the karst limestone. The aquifers are saline in near coastal areas. Recharge is mainly by percolation from upper aquifers and the total exploitable volume is considered low.

In Ninh Thuan province cleft aquifers occur in Cretaceous rock formations composed of Rhyolite. The overall volumetric water content is low and the water table varies from 2.5 m to 3 m below the ground surface. The upper Jurassic – lower Cretaceous rock layer is composed of Andesite, Dictate and Tuff. The associated aquifers have low volumetric water content.

Middle Jurassic rock formations are scattered throughout Ninh Thuan and northwest of the Phan Thiet plain but are mostly covered by more recently deposited sediments. The thickness of the aquifer ranges from 10 m to 60 m. The volumetric water content depends on crack sizes in rock formations but the total volume is considered low. Discharge from exposed streams or dug wells is 0.4 to 0.7 m^3/hour and potentially 12 m^3/hour from bore wells located near fault lines.

Weathered granite rock formations cover large areas of Ninh Thuan province with cleft aquifers occurring in tectonic cracks and cracks caused by weathering. The total volume of water contained in the aquifers is considered large. The water table occurs at around 5 m to 10 m below the surface and the thickness of these aquifers is typically 15 m to 35 m.

Estimates of exploitable groundwater resources and use

The total exploitable dynamic groundwater resource for SCC VN (including Binh Thuan province) is estimated at 4.3 Mm^3/day (sum of values quoted from water resource plans: see Appendix 2). Although the accuracy of this estimate is uncertain. During consultation meetings for this SRA, Binh Dinh DONRE stated that estimates for Binh Dinh were based on groundwater surveys covering only 30% of the province from Hoai Nhon to Van Canh. A Department of Water Resource Management (Dang 2008) review of Vietnam's groundwater resources reported that <3% of SCC VN groundwater systems have been investigated to a reliable level of detail. Estimates for the remainder are based on less reliable data generated from short duration monitoring over a limited area. The same report estimates a total dynamic reserve for SCC VN of 18.2 Mm^3/day to a maximum of 34.5 Mm^3/day. Of this the "safe" exploitable reserve is estimated at 2.4 Mm^3/day: 346,150 m^3/day is based on accurate estimates (Level A and B and C1 reserve) and 2.1 Mm^3/day is based on less reliable estimates (C2 reserve).

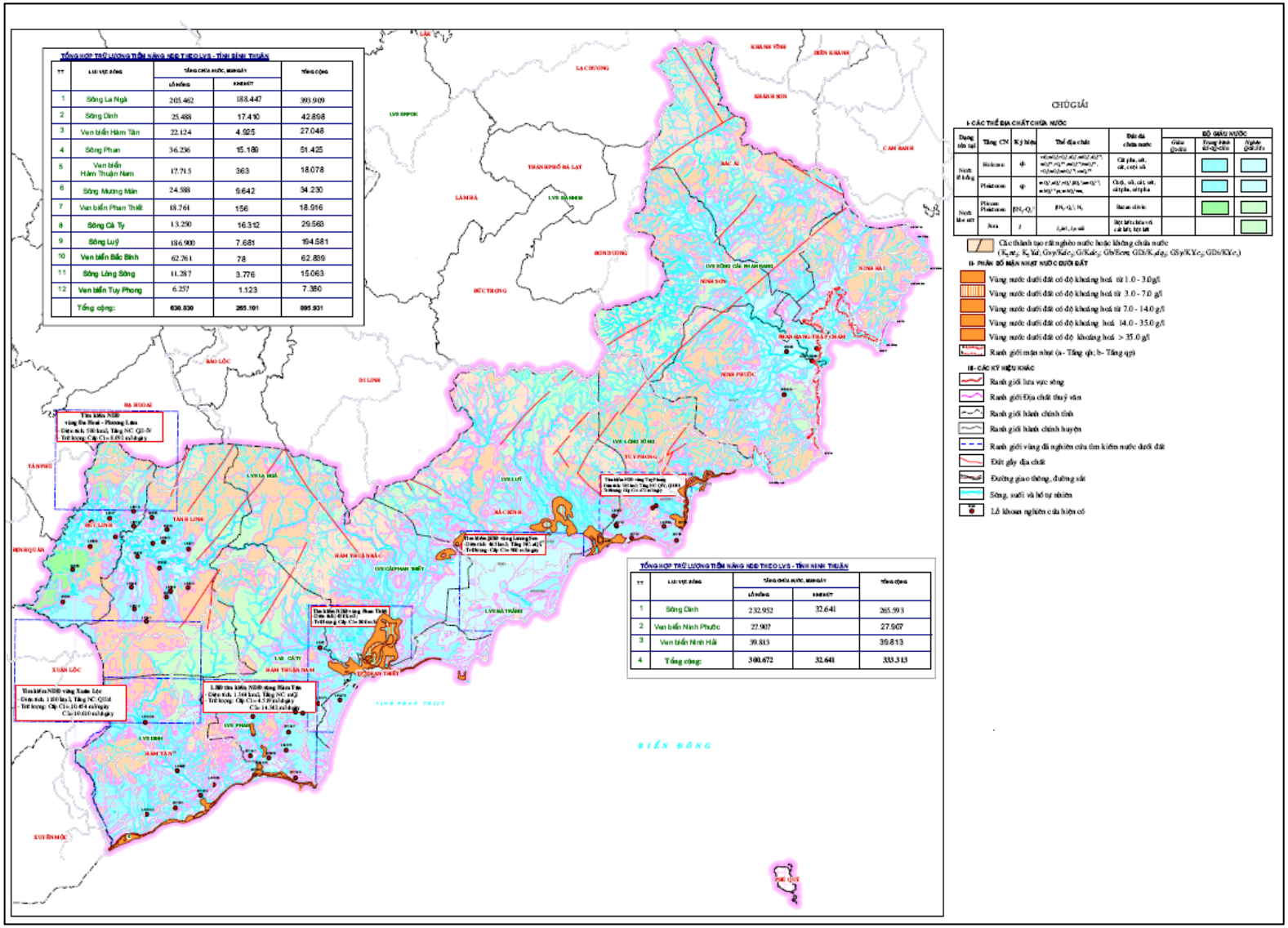

Figure 7. Groundwater aquifers of Ninh Thuan and Binh Thuan province

Using available and formally accepted information (i.e. Prime Minister approved Water Resource Plans), estimates of total dynamic groundwater storage for each province are as follows (values quoted in water resource plans: Appendix 2):

Quang Nam – Da Nang = 877,554 m^3/day

Quang Ngai = 520,419 m^3/day

Binh Dinh = 607,050 m^3/day

Phu Yen = 511,554 m^3/day

Khanh Hoa = 507,443 m^3/day

Ninh Thuan = 333,000 m^3/day

Binh Thuan = 896,000 m^3/day

During consultations and literature searches (International and Vietnamese literature) for this SRA, previous landscape scale water balance studies for groundwater dependent agriculture in SCC VN were not identified. While biophysical data is available to facilitate water balance modelling, reliable data on water volumes extracted for rural and irrigation purposes is not. Provincial NCHMF reports on Climate and Water include data on rainfall, evaporation and estimates of rainfall infiltration and run-off. Apparently, these reports are available from the Vietnamese Department of Science and Technology (VAST) website. However, these could not be located during the term of this SRA. In Water Resource Plans only estimates for groundwater use for domestic and industrial purposes for major urban centres in SCC VN are given. The volume of groundwater abstracted for irrigated agriculture and aquaculture is not mentioned. Urban water use estimates are as follows:

Da Nang city: 74,800 m^3/day for domestic-industrial use and irrigation.

Hoi An city (Quang Nam): 5,000 m^3/day from Holocene aquifers at a depth less than 30 m.

Quang Ngai city (Quang Ngai): 10,000 m^3/day from shallow aquifers along the Tra Khu river.

Quy Nhon city (Binh Dinh): 25,000 m^3/day from shallow aquifers along the Ha Thanh and Kone rivers.

Tuy Hoa city (Phu Yen): 20,000 m^3/day at Hoa Thang and 4,000 m^3/day at Hoa An from aquifers along the Da river.

Nha Trang city (Khanh Hoa): 58,000 m^3/day from Holocene aquifers along the Cai Nha Trang river.

The only other source of information on groundwater abstraction located during this SRA was Dang (2008). According to Dang (2008; data from 2005) total groundwater abstraction in SCC VN is 261.8 Mm^3/year (0.72 Mm^3/day). Of this 134.6 Mm^3/year (0.34 Mm^3/day) is abstracted from small wells by rural households, 56.5 Mm^3/year (0.15 Mm^3/day) for spring-winter irrigation of rice (10% of total rice area) and upland crops and 14.2 Mm^3/year (0.04 Mm^3/day) for aquaculture. However, Dang qualifies these estimates by stating that there are no reliable statistics on groundwater use by rural households, irrigation or aquaculture.

These estimates are based on assumptions of rural population, average water use per capita, estimated number of wells and assumed water demand of 3,000 m^3/ha per year for irrigation and 35,000 m^3/ha for aquaculture. In addition, Dang uses an estimate of 2,000 ha for groundwater irrigated agriculture and 405 ha for aquaculture. This appears to be a critical error in Dang's estimates when considering that the official statistic for the total area used for regionally important upland crops in SCC VN is 280,000 ha (Source: MARD Statistics and Food Security data base) most of which is groundwater dependant, and 15,769 ha for aquaculture. Based on these values and Dang's assumptions for water demand, groundwater abstraction is probably closer to 800 Mm^3/year (2.2 Mm^3/day) for

irrigation of upland crops and 550 Mm^3/year (1.5 Mm^3/day) for aquaculture. This would then mean that total abstraction is greater than Dang's (2008) estimated "safe" exploitable dynamic reserve of 879 Mm^3/year (2.4 Mm^3/day).

Discrepancies and inaccuracies in groundwater resource estimates indicates a need for detailed assessment of existing information to determine what else is required to obtain reliable data to support regional scale water balance modelling. While the ideal scenario leading into a new project is that all information be thoroughly reviewed, the difficulty in accessing information in Vietnam needs to be taken into consideration. There will be a need to carry over review and assessment activities to new ACIAR projects related to water resources in SCC VN.

5.4 Water resources research in SCC VN

Many studies completed in Vietnam, especially those funded by the Vietnamese government, are published in the Vietnamese literature and various project reports with only a small portion of these making their way into the international literature. The current system promotes this with academic career progression giving more weight to publication in Vietnamese journals. Thus it is difficult for non-Vietnamese readers to access information in Vietnam when it is available in Vietnamese language only. Chu Thai Hoanh (IWMI) assisted with identifying, translating and interpreting Vietnamese articles discussed in the following section. Chu Thai Hoanh's full review is provided in Appendix 2.

Research with direct Vietnamese central and provincial government funding

ASISOV is the principal agricultural research institute for the SCC VN region. ASISOV's focus is predominantly on crop technology and management. Irrigation and water resource management research were introduced to ASISOV through their involvement in SMCN 2003/035 and SMCN 2007/109. Much of their varietal evaluation work is undertaken to develop cultivars that are tolerant of drought, acidic soil and salinity. Between 2006 and 2010 ASISOV undertook 88 studies in collaboration with other Vietnamese institutes, mostly focused on production technologies for rice, peanut, green peas, soybeans, taro and cashew. Key projects funded directly by the Vietnamese government are shown in Table 1.

VAWR is located in Hanoi, which is remote from SCC VN, but has implemented several water resource studies in the region, mostly in Ninh Thuan and Binh Thuan (Table 2). As an agency under MARD, VAWR mostly focus their research efforts on surface water although groundwater features in some of their research. Studies with most relevance to on-farm water management in SCC VN include those listed as No. 2, 7 and 9 in Table 2.

The study listed as No. 2 in Table 2 was led by Associate Professor Nguyen Quang Trung (Trung, 2008) with Plastro, an Israeli-Australian company, participating as a private sector coinvestor. Primary outputs from this study were adapted irrigation scheduling and low cost pressurised and filtered drip irrigation for dragon fruit in Binh Dinh province and table grapes in Ninh Thuan province. The outcomes from the study led to the development of a Vietnamese standard for irrigation of dragon fruit and table grapes which will soon be promulgated by the General Department of Standards and Quality Measurements.

Table 1. Agricultural studies in the SCC VN by ASISOV related to field water management

No.	Title	Budget ($AUD equiv.)	Funding source	Duration
1	Testing of technologies in growing grass on dry sandy soil under desertification for cattle in Ninh Thuan province.	24,000	MARD	2006-2008
2	Selection of rice varieties and cultivation techniques to improve productivity in the areas with agricultural constraints (water shortage, acid soils, salinity) in Binh Dinh province.	20,750	DOST of Binh Dinh	2007-2009
3	Scientific and technological alternatives for efficient exploitation of sandy soils in the SCC VN.	32,500	MARD	2007-2009
4	Selection and generation of drought-tolerant rice varieties and cultivation techniques for the SCC VN and Central Highlands.	55,000	MARD	2009-2011
5	Integrated cultivation techniques of cassava on coastal sandy soils and hilly lands to achieve high productivity and sustainability.	60,000	MARD	2009-2011
6	Testing of new fruit varieties (custard apple, apple, guava, pomegranate) in semi-arid areas of Ninh Thuan province.	7,500	MARD	2009-2011
7	Selection, generation and development of drought-tolerant and short duration peanut and soybean varieties in the SCC VN and Central Highlands.	165,000	MARD	2011-2015
8	Demonstration of drought-tolerant rice varieties (TH207, CH208) in Binh Dinh Province.	10,000	MARD	2012
9	Improvement of soil fertility in the coastal desert areas by combining local organic fertiliser with modern water saving techniques.	48,800	Ninh Thuan agricultural competition	2012
10	Selection and generation of high yielding saline-tolerant peanut varieties suitable for the Central Coasts of Vietnam.	168,500	MARD	2012-2014
11	Selection and generation of drought-tolerant rice varieties for the SCC VN and Central Highlands.	140,00	MARD	2012-2016

Note: $AUD 1 = 20,000

Table 2: Water resources studies in the SCC VN undertaken by VAWR

No.	Title	Budget ($AUD)	Funding source	Duration
1	Technical alternatives of water control structures for aquaculture at different ecosystems.		Central Gov.	2001-2004
2	Applications of water saving techniques for grape and dragon fruit in Ninh Thuan and Binh Thuan provinces		Central Gov.	2006-2008
3	Development and applications of agro-forestry systems integrated with water management for rehabilitation of degraded sandy soil ecosystems in the SCC VN	90,000	MARD	2007-2009
4	Recommendations for contents and methodologies of indicators in assessment of surface water resources applying in sustainable basin management.	12,250	MARD	2008-2009
5	Rehabilitation of seriously degraded agri-aquacultural systems in the coastal zones	65,000	MARD	2007-2010
6	Applications of scientific and technological alternatives in drought prevention for sustainable agriculture in the Central Vietnam	165,000	Central Gov.	2008-2010
7	Alternatives for prevention of desertification and recovery of ecosystems in the SCC VN	18,500	MARD	2008-2010
8	Scientific base in drought and desertification for establishment of a management system and recommendations to eliminate negative impacts (study locations: Red river delta and SCC VN)		Central Gov.	2008-2010
9	Technological process and equipment suitable for sugarcane in large production areas	125,000	MARD	2011-2013
10	Identifying capacity and minimum flow of Vu Gia and Thu Bon rivers	4,350	Central Gov.	2013-2015

Note: $AUD 1 = 20,000

The 2006-2008 VAWR irrigation study extended into the project listed as No. 6 in Table 2. A PhD study associated with the project was conducted by Le Xuan Quang (Quang and Hai 2010, 2012a, 2012b). Le Xuan Quang's study focused on irrigation for dragon fruit. The results from this study indicated highest yields were achieved when soil moisture was maintained at 60-100% water holding capacity with water usage at development stages of: Year 1 = 725 to 843 m^3/ha; Year 2 = 1,097 to 1,380 m^3/ha; Year 3 = 1,536 to 1,803 m^3/ha. Le Xuan Quang also trialled partial root zone drying (PRD) as a strategy to reduce water consumption during periods of low water availability. PRD reduced water consumption by up to 40% without yield consequences.

In addition to Le Xuan Qang's study, this project investigated drought prevention strategies for sustainable agriculture in Central Vietnam (Tuan 2011a, 2011b). CROPWAT, CLIMWAT, AQUASAT were utilised to forecast crop water requirements for dragon fruit and table grapes and the DSS-RO reservoir model was evaluated for operational management of the Tam Giang reservoir in Ninh Thuan province. A number of approaches to site specific water harvesting and storage for drought and desertification prevention were also demonstrated (Figure 8):

Sub-surface water harvesting and storage for domestic use and livestock: Hoa Thuy, and Tu Tam hamlets of Phuoc Hai village, Ninh Phuoc district, Ninh Thuan province. Groundwater discharged from beneath sand dunes was harvested via a pipeline system installed at 3 m depth with water pumped to an open concrete storage tank of 20 m^3. Water from the tank was filtered and utilised for domestic use and livestock by 20 households.

Sub-surface water harvesting and storage for agro-forestry irrigation: Hoa Thuy hamlet of Phuoc Hai village, Ninh Phuoc disctrict, Ninh Thuan province. The water collection system comprised of a pond 2 m x 15 m x 3 m depth (30 m^3) at the base of a sand dune. A diesel pump was used to deliver water to irrigate neem trees, fruit trees and some annual crops.

Rainwater harvesting on sand dune slopes: Hong Phong village, Bac Binh district, Binh Thuan province. A concrete or plastic storage tank was installed below ground level on the slope of a hill and the tank was covered with plastic sheeting to reduce evaporation. PVC pipes were installed to distribute water by gravity or small pumps to irrigate various crops. The system was installed with a mixed crop productive garden urrounding it. The mixed crop system consisted of a living fence of jatropha trees, neem trees acting as wind breaks, perennial fruit or industrial tree crops and annual crops.

Conclusions from study No. 6 (Table 2) indicated that drought has become more severe and is affecting more areas in SCC VN than in the past. Possible reasons given for this include:

- insufficient water inflows
- climate change
- inappropriate parameters applied in design of water infrastructure
- degradation of irrigation infrastructure causing large water losses in distribution systems that could not satisfy water demand
- insufficient capacity in reservoir operation causing waste and irrational water supply
- inflexibility in adjustment of cropping system and calendar, and cultivated area to adapt to variation in water supply
- increasing water demand for different purposes in the recent years is causing high competition in water use
- limitation of policy and regulations in water management that does not encourage water saving

Recommendations from study No. 6 (Table 2) included:

- Implementation of a three step approach to drought adaptation: precaution, early warning and limiting impact of drought.
- Apply DSS-RO model with linear programming technique for reservoir operation during drought conditions.
- Study and implement water saving irrigation methods for crops tested during study to minimise yield losses due to drought.
- Further research to determine water use efficiency methods for crops other than dragon fruit and table grapes.
- Further research on water harvesting and storage methods and to improve soil water holding capacity.

The aim of the project listed as No. 9 in Table 2 was to design and evaluate cost effective irrigation hardware equipment for commercially grown sugarcane in Quang Ngai and Phu Yen provinces. This project is still progressing and results have not yet been reported. However, the project is of interest because the irrigation hardware developed through the project may be available for evaluation with other crops during future ACIAR projects in the region.

Research projects funded by International donors

Large foreign donors such as the Asia Development Bank (ADB) support development work for surface water infrastructure but related research receives limited attention from international donors. This is possibly because MARD have much human capacity in this field and already puts significant resources toward surface water research. The primary focus for many international donor research projects in SCC VN has been Binh Thuan and Ninh Thuan. Although, Quang Nam has also received recent attention. A large proportion of the known international donor research projects focus on assessing exploitable groundwater to supply potable water for domestic use.

The project titled *"Groundwater artificial recharge and salinisation prevention as a drought-fighting measure in central coastal areas of Vietnam"* (Schafmeister and Hoang, 2001) was completed in 2001 through collaboration between Ernst Moritz Arndt University Greifswald, Germany and the Council of Natural Resources and MOSTE of Vietnam. The project was located in the Luy River delta of Binh Thuan province with the primary aim of modelling artificial groundwater recharge and scenario testing for measures to mitigate sea water intrusion. Results from modelling indicated that a recharging trench covering a total area of 1 km^2 could potentially divert an additional 133 m^3/day to 300 m^3/day water to the local aquifer. This estimate was based on rainwater infiltration of 10% to 15%. Scenario testing for seawater intrusion mitigation indicated that the most effective, but also most expensive, option for preventing further seawater intrusion into the Luy Delta aquifer was to construct an underground slurry dyke system. After installation of the dyke, saline water would be pumped from wells installed near the dyke wall out to sea. Despite promising results from scenario modelling, the initiatives proposed by this study do not appear to have been implemented.

Between 2004 and 2010 a large project titled *"Augmenting groundwater resources by artificial recharge in Binh Thuan province, Viet Nam"* project (IHP, 2011) was completed by a consortium involving: UNESCO, the University La Sapienza, Italy, GEOKARST, VAST, Binh Thuan DARD and DONRE, Division 8, Vietnamese Institute of Nuclear Science and Technology. The project was funded by the Vietnamese Government (Ministry of Environment), ICSU (the International Council for Science), UNESCO and the Italian Government (Ministry for the Environment, Land and Sea). The main aim of the project was to improve knowledge of groundwater resources under the sand dunes of Binh Thuan province (Figure 9) and facilitate provision of drinkable water to several drought affected communities in Binh Thuan.

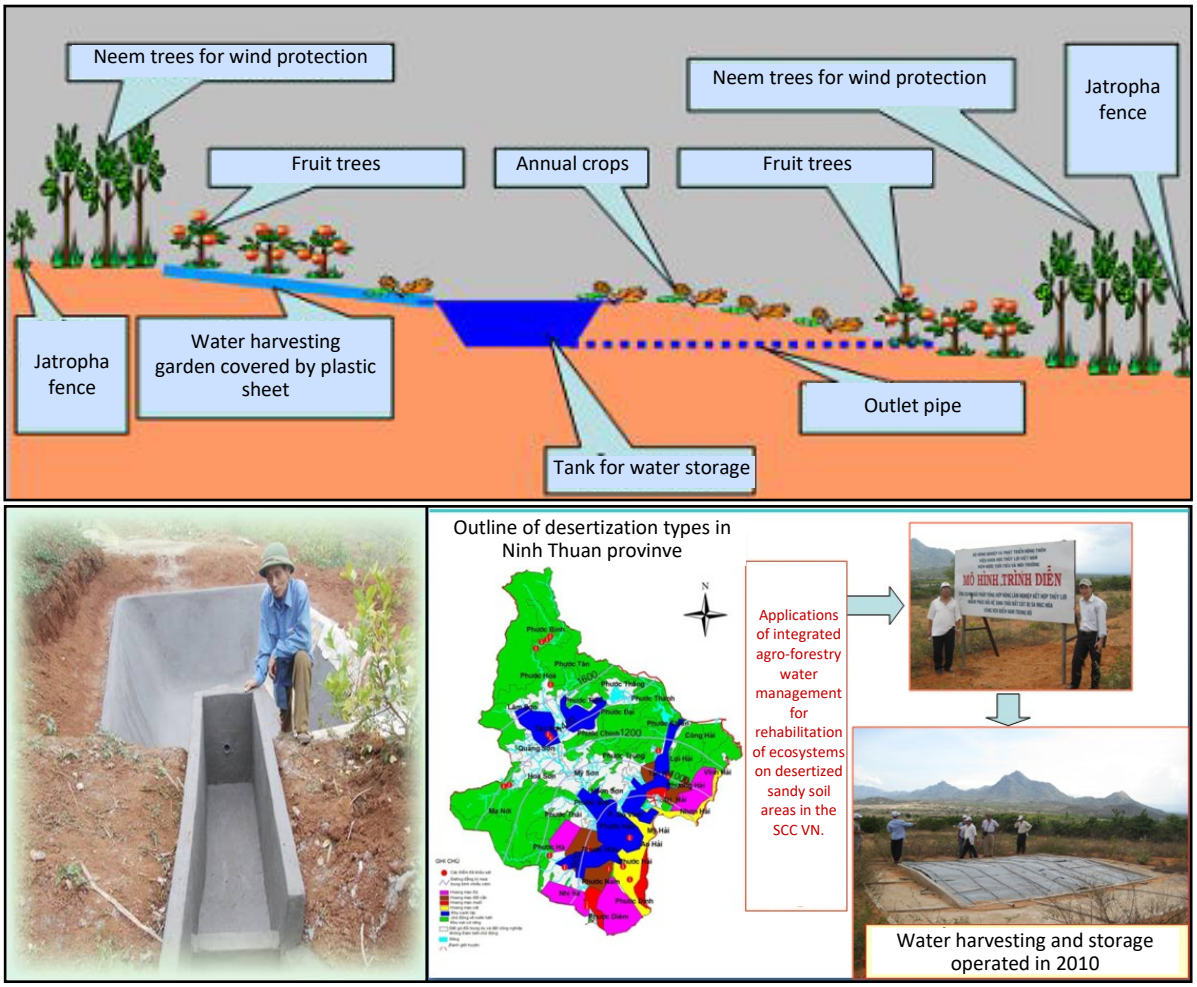

Figure 8: Demonstration of water harvesting and storage in Ninh Thuan province
Source: see Appendix 2

Extensive field investigations, hydrogeological and geophysical surveys, installation of water wells, design and installation of groundwater and meteorological monitoring systems and water sampling for chemical and isotope analyses, were carried out. Capacity building during the project extended to ~200 Vietnamese participants and involved knowledge and competency development in artificial aquifer recharge, the use of stable isotopes in hydrology and hydrological methods for field survey.

This project was also the first to implement an artificial aquifer recharge pilot project in Vietnam. The pilot project was established in the Bau Noi well field. A 5 km pipe was installed to supply water to Hong Phong village for domestic and agricultural use. Monitoring of observation wells at Bau Noi confirmed that the use of artificial recharge potentially provided ~220 m^3/day of drinkable water for Hong Phong village.

The Groundwater Modelling System software, GMS version 3.1, was utilised during the project to determine groundwater potential and sustainable yield (Figure 10). Modelling was applied to determine water budget components and to predict the impacts of proposed groundwater abstraction as well as from artificial aquifer recharge. The steady state model indicated that the Bau Noi well field in Binh Thuan has a dynamic groundwater reserve totalling 0.23 Mm^3/day with a sustainable yield of ~0.14 Mm^3/day. The unsteady state model indicated a dry season (December to March) minimum dynamic reserve of 0.11 Mm^3/day with a sustainable yield of 0.04 Mm^3/day. The wet season maximum dynamic reserve was estimated at 0.47 Mm^3/d with a sustainable yield of 0.2 Mm^3/d, respectively.

The outcomes from this project have developed much interest from within and outside Vietnam. In 2010, the Italian government approved €15.6 million for a project titled "Drought alleviation for Binh Thuan province: construction of water supply facilities for domestic use, production and reforestation". This project will supply water for a large part of the province to address deforestation and desertification and provide water for human consumption, agriculture and reforestation purposes.

The project titled "*Improvement of groundwater protection in Vietnam - IGPVN*" commenced in 2009 with phase 1 completing in 2010. Phase 2 of this project is ongoing until 2014. The project is funded by the German Ministry for Economic Cooperation and the primary partners are Bundesanstalt für Geowissenschaften und Rohstoffe (BGR-Institute for Geosciences and Natural Resources), Germany and CWRPI (Division 7) with collobartive partners including collaboration with Nam Dinh, Ha Noi, Ha Nam, Soc Trang and Quang Ngai DONREs. Phase 1 of the project focused on the central Vietnam province of Nam Dinh in the Red River Delta. Phase 2 has extended to other provinces in Vietnam including Quang Ngai province in SCC VN.

The project focuses on capacity strengthening for groundwater planning and investigation for urban areas. Groundwater utilisation for agriculture is not a main objective for the project but outputs include relevant data and groundwater resource assessments (Figures 11 and 12). Activities within this project aim to facilitate a participatory approach in groundwater resource protection through improved communication and information flow between each level of government and stakeholders. The project supports activities relating to seawater intrusion, groundwater pollution, interpretation and management of hydrogeological data, improving groundwater monitoring networks, defining groundwater protection zones and extraction limits and strategies for sustainable utilisation of groundwater resources. BGR has also been assisting CWRPI to design a hydrogeologic database and improve capacity in application of modern methods and technologies in data processing and analysis. The project also aims to facilitate improvements to internal and external data exchange and workflow.

During the Phase 1 pilot stage several topics were pursued in Nam Dinh province:

- Groundwater salinisation by seawater intrusion
- Groundwater pollution due to sewage and industrial pollution sources
- Management and interpretation of hydrogeological and related data using GIS
- Improvement of the monitoring network
- Definition of groundwater protection zones and extraction limits
- Strategy development for exploitation and utilisation of groundwater and sustainable development of groundwater resources.

Recommendations to emerge from phase 1 include the following measures to address groundwater overexploitation and salinisation: (i) enforcement of regulation to control extraction; (ii) registration and extraction licensing; (iii) central water supply based on treated surface water; (iv) reducing extraction by identification of sources for groundwater loss or misuse, alternatives for groundwater usage and awareness campaigns; (v) optimising extraction; (vi) conjunctive usage; and (vii) groundwater monitoring.

Ninh Thuan province has been the subject of groundwater salinity surveys under a project co-funded by UNESCO and Vietnamese and Italian governments. The project is titled "Impacts of sea level rise by climate change on coastal zone and Islands in Central Part of Viet Nam" and commenced in 2006. The UNESCO project leader, Dr Giuseppe Arduino, was contacted during this SRA. There have been some delays in implementing the project and so it is ongoing at this stage. At the time of writing a final report had not been released but a project brochure indicates that adequate data has been collected to conclude that increasing groundwater salinity is primarily caused by: 1) over extraction,

mostly for irrigation, of brackish water from shallow coastal sand dune aquifers; 2) industrial salt production in Ninh Thuan. The situation is expected to worsen and spread further inland.

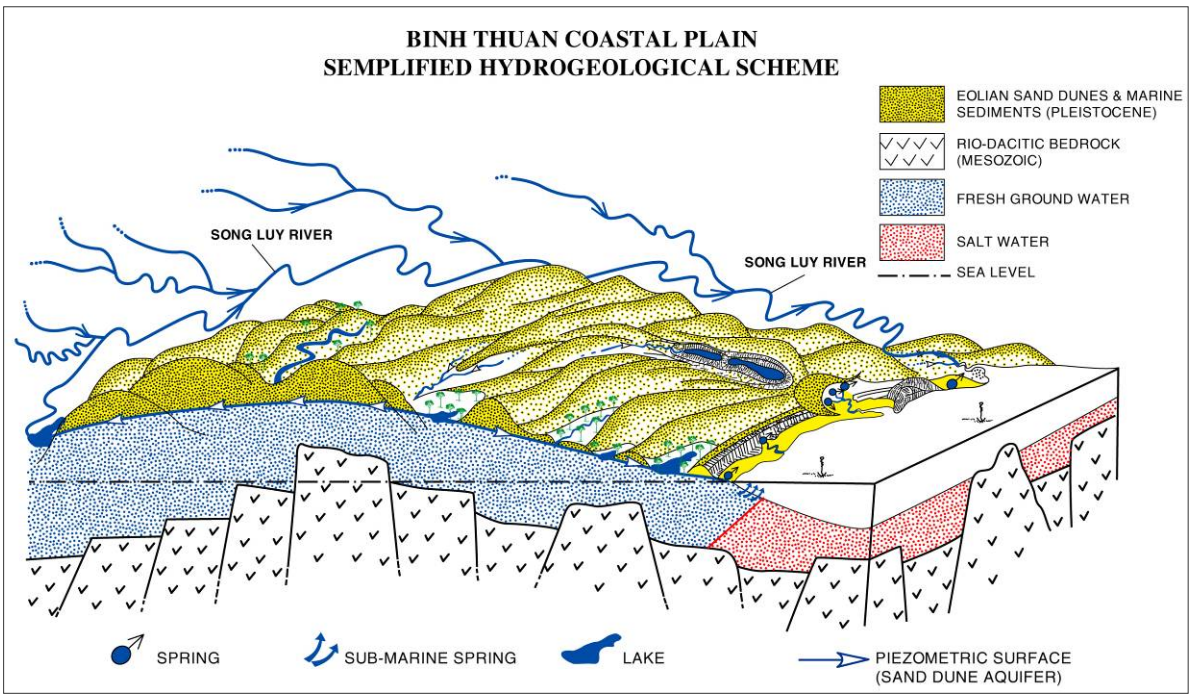

Figure 9: Simplified hydrogeological scheme of Binh Thuan province (IHP, 2011)

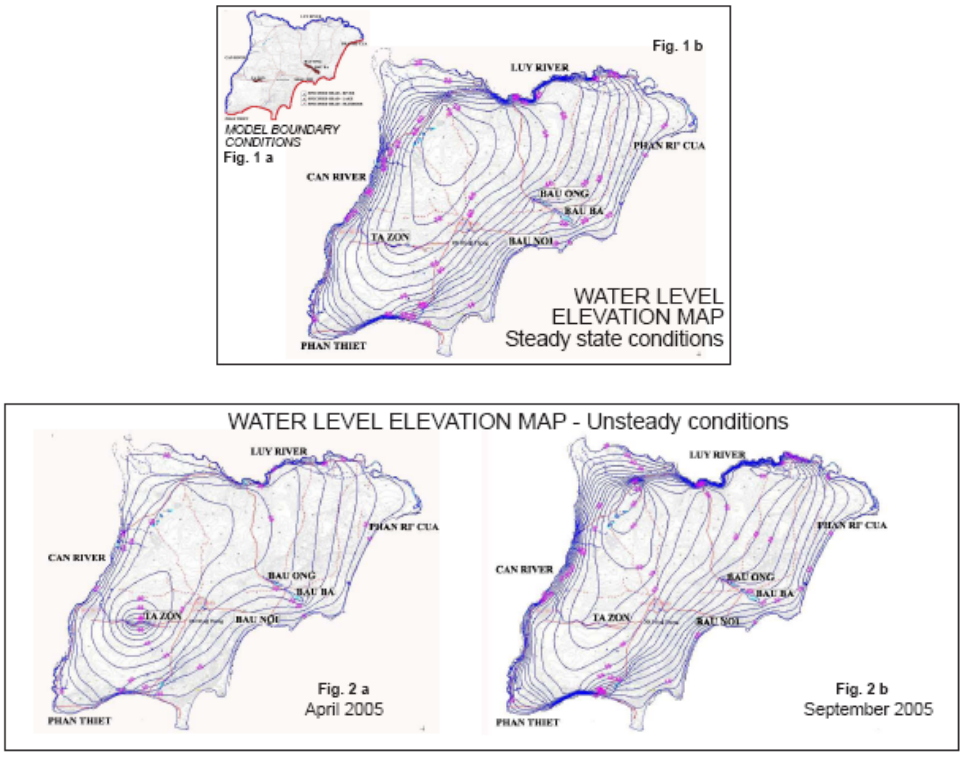

Figure 10: Water level elevation simulated by groundwater flow model (IHP, 2011)

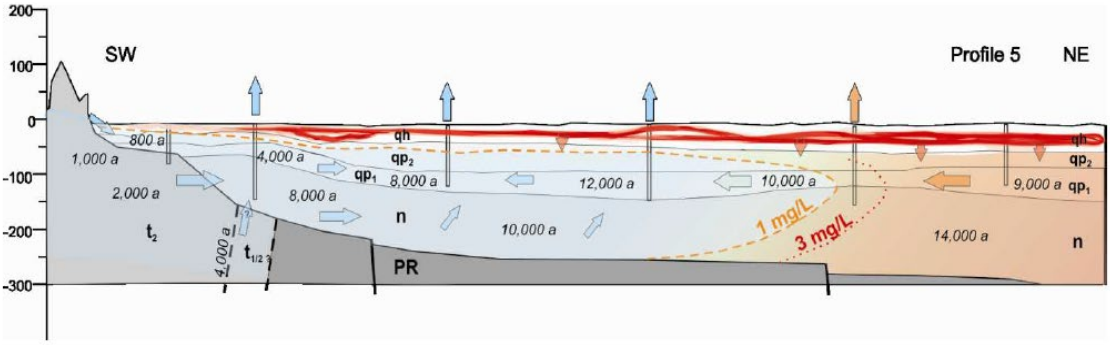

Figure 11: A conceptual cross-section demonstrating some major results regarding groundwater salinity and flow in Pleistocene (qp1, qp2) and Neogen (n) aquifers (CWRPI and BGR, 2011). Colours indicate: fresh (blue), brackish (orange) and saline (red) pore water; Italic figures indicate groundwater ages in years (a); Further hydrogeological units: Triassic hardrocks (t1, t2) and Proterozoic basement (PR).

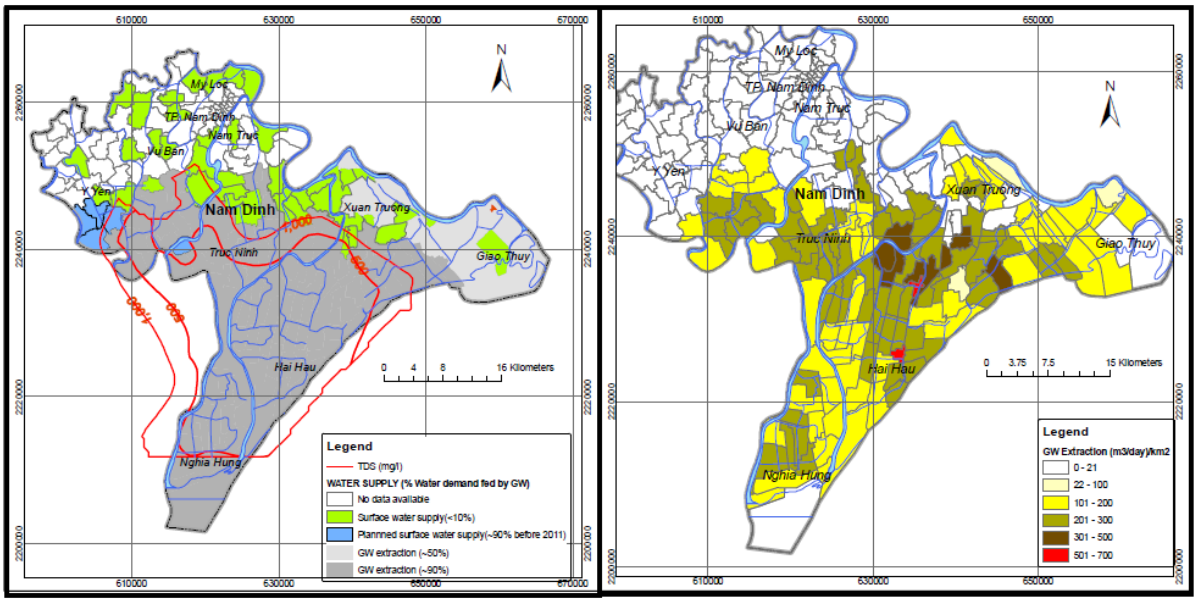

Figure 12 - left: Portion of groundwater used for communal water supply in Nam Dinh province based on the information collected during a field survey in 2011 (n=167). Red line indicates salinity boundary (mg/L) in Pleistocene aquifer. right: Calculated amount of extracted groundwater (m^3/day/km^2) based on survey of domestic communal water supply.
Source: CWRPI and BGR, 2011

The only foreign donor projects to have conducted on-farm applied research related to water resources in SCC VN appear to be ACIAR projects SMCN 2003/035 and SMCN 2007/109. Under SMCN 2003/035 ASISOV carried out field irrigation experiments with cashew, mango and table grapes in Binh Dinh and Ninh Thuan. Under SMCN 2007/109 ASISOV also carried out irrigation experiments with groundnuts in Binh Dinh province. These were the first on-farm water use field experiments that ASISOV had been involved in.

Field experiments with cashew demonstrated productivity gains from extending the duration of irrigation from the standard practice of flowering only to irrigating from flowering through to nutset. Water savings were achieved in cashew and grapes using drip irrigation. Mini-evaporation pan irrigation scheduling was also introduced to cashew, mango, grape and peanut cropping systems (Figure 13). In both Binh Dinh and Ninh

Thuan, cashew yields increased significantly with the mini-evaporation pan. The total volume of water applied was greater than that of the farmers' practice and the irrigation interval also increased, which increased labour costs. Water use efficiency was improved with mangoes and the volume of water applied to grapes was halved without a yield penalty. Mini-evaporation pan irrigation scheduling resulted in 14% to 49% increases in peanut yields and significant water savings.

Figure 13. From left: the hose pull irrigation method in cashew orchards and a mini-evaporation pan.

While several reviews of water resource policy in Vietnam have been undertaken at a national level (Hirsch et al. 2005; Kellogg and Brown 2009; Can Tho University 2011). None of these have specifically focused on examining the impacts of water resource policy on communities in SCC VN. A study due to complete in June 2013 titled *"Linking increases in water use efficiency for food production at the farm scale to global projections"* aims to improve policy and instruments available to farmers and policy makers for increasing water use efficiency in agricultural food production. This study is funded by the German Government via BMZ and is being implemented by the Leibniz Institute for Agricultural Engineering Potsdam-Bornim (ATB), International Food Policy Research Institute (IFPRI) and SIWRP.

This project is mostly focused in Ninh Thuan province and combines a local farm scale approach with a global modelling approach to: estimate agricultural water flows; the costs of water in production at the farm scale; improve projections for agricultural water use at the regional and global levels for policy makers. The study is based on a methodology for farm scale water flow balance developed at ATB and the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed at IFPRI. IMPACT simulates both water supply and water demand for all water users including water use for food production (supply and demand modes). At the time of writing the report for this project was being prepared with an estimated completion date of July 2013.

6 Water, soil and commodity priorities for SCC VN

At consultation meetings, participants were asked to state their organisation's perspective on the research priorities for SCC VN. A relatively large list of priorities was nominated. These priorities were grouped into key themes as outlined below.

6.1 Climate and water resource priorities

Climate risks in SCC VN are mostly associated with climate variability, drought and flood. This was recognised by nearly all agencies consulted. Lowland flooding can occur on an almost annual basis. Flood mitigation engineering is considered a priority for relevant agencies. However, the scoping study team also noted research being undertaken on novel flood adaptation approaches such as hanging gardens to raise vegetable and herb beds above shallow flood water (Hue University).

Drought and water shortages have the most impact at around 3- to 4-year intervals. Increasing headwater reservoir storage and upgrading channel infrastructure appears to be the primary strategy to manage water shortages. However, this strategy is only effective for lowland crops, rice in particular. There does not appear to be a water shortage management strategy in place for upland crops, especially those dependent on groundwater for irrigation. Selection of drought tolerant crops and livestock is a primary focus for upland areas.

There is much concern among agencies regarding the future impacts of climate change and sea level rise on agriculture. The main trend for research in this area has been on assessing the resilience and capacity of communities to adapt to climate change. There also appears to be a focus on assessing the likely impacts of climate change on agriculture and communities (e.g. MONRE, 2003, 2008, 2009a, 2009b; Natural Disaster Mitigation Partnership, 2007). Sea water intrusion into rivers and coastal aquifers was frequently raised during consultation meetings. Breeding, bio-engineering and selecting salt tolerant crops were frequently suggested as possible adaptation strategies. Most agencies cited sea level rise and over exploitation as key issues affecting sea water intrusion. There are a number of past and current projects that have identified the problem and areas affected by sea water intrusion (examples given in Section 5.4) but few of these are based in SCC VN and there appears to be little research or action toward developing and implementing avoidance strategies. The main reason for this is that the Vietnamese government and donors are focused on seawater intrusion in the larger production and densely populated areas of the Red River and Mekong River Deltas.

The following list summarises thematic research priorities for SCC VN to emerge from consultation meetings (November 2012):

Climate

- Climate change / variability and sea level rise adaptation (ICD-MARD, VAAS, NIAPP, VAWR, HUAF, DARD, DONRE).
- Research to understand resilience of communities to adapt to climate change (VAAS, NIAPP, HUAF).
- Identify cropping patterns to adapt to climate change / variability / drought / increased salinity due to sea water intrusion (NIAPP, VAAS, Division 7, HUAF, DARD, ASISOV).
- Assess status of desertification in SCC VN and strategies to prevent desertification (NIAPP).
- Hanging gardens as a flood adaptation strategy for small area crops (HUAF).

Water resource management and water use management

- Evaluate affordable irrigation technologies (irrigation hardware and scheduling) and cropping patterns to improve on-farm water use efficiency (NIAPP, VAWR, ASISOV).
- Water balance modelling / crop modelling (VAAS, VAWR, NLU).
- Build farmer awareness that water is a finite resource and capacity in irrigation and efficient water use management. Support for large field demonstration and training programs (VAAS, VAWR, Division 7, ASISOV, DARD).
- Focus on improving water use efficiency in crops that use the most amount of water e.g. peanut in Binh Dinh and maize in Quang Nam (SFRI, ASISOV).
- Examine problem of farmers not registering wells and water losses and contamination caused by digging and subsequent abandonment of temporary wells in drought periods (DONRE BD).
- Modelling to determine best ways to allocate surface water supply to rice during water shortages (IWRP, SIWRP).
- Develop decision support software for surface water allocation (NIAPP, VAWR).
- Improve integration between landuse planning and irrigation scheme planning (NIAPP).
- Research to better understand the impact of dams and reservoirs on coastal rivers and aquifers (HUAF).
- Upgrade / construct more irrigation infrastructure – lining channels / patching leaks / moving irrigation water over roads / improve and build more reservoirs (Binh Dinh DARD).
- Improve utilisation of NCHMF climate data by DARDs through communication of daily ET and rainfall so that farmers can estimate crop water requirements (added by scoping study team).

Groundwater

- Low provincial capacity in water research in SCC VN, need to increase capacity (ICD-MARD)
- Planning and regulation for farmers accessing groundwater (VAWR, DWRPIC).
- Integration of groundwater and surface water resource exploitation and management (VAWR).
- Improve knowledge of groundwater quality, landuse impacts on water quality and sustainable exploitation (NIAPP, VAWR, HUAF, Division 7, NLU, DONRE).
- Integrated nutrient and water management and livestock management to reduce nutrients leaching to groundwater (SFRI, Division 7, NLU, ASISOV, DARD).
- Improve knowledge of areas affected by sea water intrusion into coastal rivers and aquifers (IWRP, NIAPP, VAWR, DWRPIS, Division 7, HUAF, DARD, DONRE).
- Select salt tolerant crops and adapt cropping systems to increased groundwater salinity (VAAS, NIAPP, HUAF, DARD, ASISOV).
- Improved storage of wet season rainfall and runoff and managed aquifer recharge as a strategy to manage water shortages (NIAPP, VAWR, Division 8, Division 7).
- Improve knowledge of impact of aquaculture (shrimp farming in particular) on groundwater and regulation to avoid over extraction by aquaculture industries (Division 7, HUAF, DONRE, DARD).

6.2 Soil resource priorities

Planning and resource agencies within Vietnam have a strong desire for investment in research to overcome constraints associated with the low fertility sands of SCC VN. Two main approaches to overcoming soil constraints were raised during consultation meetings. The first is to alter soil conditions to accommodate specific crops. The second is to select crops adapted to the conditions. Integrating both approaches builds resilient farming systems.

Consulted agencies stated that there was a need for further research on clay and organic soil amendments for sandy soils. Dr Bo (President, VAAS) stated that there are 14 to 15 million tonnes of crop residues produced annually in Vietnam, a sizeable proportion of which is disposed by burning, and that utilisation of these as soil amendments will reduce green house gas emissions. Recent surveys have also indicated that 50% to 60% of solid waste consists of putrescibles (HUAF; DONRE). Municipal waste separation, collection and management of solid putrescibles by composting is beginning to emerge in the major centres of SCC VN. Utilisation of recycled organics and carbonised organic matter (biochar) as soil amendments has strong potential to improve soil constraints. However, specific research is needed to confirm their potential, determine appropriate application rates and context for their use and to avoid use of contaminated materials.

The following list summarises soil resource research priorities for SCC VN to emerge from consultation meetings:

- Research to determine the most appropriate use and management for the four classes of sandy soils in SCC VN (NIAPP, ICD-MARD, ASISOV)
- Research to improve the water holding capacity of sandy soils (SFRI, ASISOV, DARD).
- Research to improve the nutrient retention and fertility of sandy soils (SFRI, ASISOV, DARD).
- How to build carbon in sandy soil in a tropical climate? (SFRI, ASISOV).
- Integrated nutrient management (HUAF).
- Cost effective management of micro-nutrient deficiencies in sandy soils (ASISOV).
- Integration of nutrient and water management to improve fertiliser use efficiency and nutrient losses due to runoff and leaching (SFRI, ASISOV).
- Clay amendments for sandy soils and compressed clay mixed with biochar products (VAAS, VAWR, SFRI, ASISOV).
- Biochar production techniques to optimise biochar soil amendments (VAAS, SFRI, ASISOV, DARD).
- Waste water collection, treatment and utilisation as a soil amendment (DONRE)
- Organic matter soil amendments / crop residue / green manure research (SFRI, ASISOV).
- Biological fertiliser research (DARD Phu Yen, NLU, HUAF).
- Improve utilisation of organic residues in coastal areas; how to reduce export (by lowland famers selling to highland farmers) of manures, composts and biochar to highland areas where it is mostly used to grow coffee (DARD Binh Dinh).
- Managing problem of manures and composts contaminated with weed propagules (DARD Phu Yen).
- Ameliorating and preventing soil salinity (DARD Binh Dinh).
- Agro-economic modelling of soil amendments prior to field evaluation (NLU).
- Resource assessment of off-farm organic residues with potential for utilisation as soil amendments (HUAF).

6.3 Farm commodity priorities

In July 2012 MARD released "Draft No. 2 of the Restructuring of the Agriculture Sector for Increasing Value Adding and Sustainable Development". The plan nominates three priority crop groups and lists specific farm commodity priorities for each region.

1. Crops with high competitive advantage and high potential for value adding.
   Priority crops for SCC VN:
   - Cashew
   - Pepper
   - Cassava
2. Crops with high development potential
   Priority crops for SCC VN:
   - Vegetables and fruits
3. Crops with average development potential and competitive advantage
   Priority crops for all regions:
   - Maize
   - Sugarcane
   - Peanuts
   - Soybean

When, during consultation meetings, Vietnam government agency representatives were asked to nominate research priorities for water and soil resources in SSC VN, the conversation frequently commenced with crop types. Encouragement was given to consider other priorities first and then prioritise criteria for selecting crops rather than specifying the priority crops.

Dr Bo (President, VAAS) offered four criteria to consider when selecting crops for research in SCC VN:

- Focus on crops with comparative advantage.
- Work with crops to reduce dependence on imports (e.g. maize and soybean) and Chinese export markets.
- Focus on three crop groups: 1) food staples (e.g. rice, sweet potato as grows in sandy soil and has low water requirement); 2) legumes; 3) other annual crops.
- Choose crops that have post-harvest and storage constraints and work to overcome these.

Other criteria for selecting crop types raised during consultation meetings included:

- Select irrigated crops that cover large land areas; to maximise impacts from improving water use efficiency.
- Select crop types that have a low water requirement and are tolerant of dry conditions.
- Crop types that are tolerant of saline soil and irrigation water.
- Select higher value crops; those that are likely to increase farm income.

Among the national level planning institutes there was a desire to prioritise rice. During several consultation meetings suggestions were put forward to focus on reducing total water demand, especially in low water availability periods, by cutting back from three to two rice crops per year, with a low water requirement upland crop rotation in between. Development of salt tolerant rice varieties was also raised. In addition to rice, a relatively long list of possible farm commodities to prioritise was collated, with or without specific rationale for selection.

Specific farm commodities raised as priorities for SCC VN were as follows:

- Based on a rural industry development plan that extends to 2020 (quoted by DARD Binh Dinh), farm commodity priorities for SCC VN are formally: rice, peanut, maize, cassava, sugarcane; coconut, cashew, mango (market issues), livestock.
- Both ASISOV and Binh Dinh DARD indicated that peanuts are a high priority for SCC VN as they are an important cash crop and they cover a large land area. Phu Yen DARD, however, did not consider peanuts a priority as there were only ~1,000 ha of peanuts grown in Phu Yen province.
- ASISOV and DARD Binh Dinh indicated that cassava was a priority. In lowland areas cassava can be affected by wet soil conditions near harvest and there is a need to improve yields in raised elevation areas where wet soil conditions are less of an issue.
- Vegetables grown on sandy soil was raised as a priority by Phu Yen and Ninh Thuan DARDs.
- Agronomic research and promotion of sesame seed as a drought tolerant crop was nominated by ASISOV and Phu Yen DARD.
- Even though cashew production is declining in SCC VN, cashews remain a priority as they cover a large land area and are important for the national export strategy (ASISOV, DARDs).
- ASISOV stated that further mango nutrition research is required.
- Promote expansion of Jujube (Vietnamese apple) in Ninh Thuan. Jujube prefers sandy soil, has low demands and is drought and salinity tolerant (NIAPP).
- NIAPP, NLU and DARD Ninh Thuan prioritised promotion of Cactus grown for fibre, especially on currently unused/ marginal land. Past crop evaluation results have been impressive but farmers have not been inspired to produce fibre cactus.
- Investigate potential for growing crops for biofuels (NIAPP, DARDs).
- Cattle, sheep and goat husbandry and irrigated and drought tolerant forages for Ninh Thuan was raised as a priority by NIAPP, NLU, ASISOV, DARD Ninh Thuan.

7 Water and soil research opportunities for ACIAR

Following consideration of advice from consultations in Vietnam (Appendix 1) and the information review (Appendix 2), emergent issues, key priorities and opportunities were identified. The following discussion outlines opportunities and priorities compatible with ACIAR's priorities for Vietnam.

7.1 Surface water sustainability

Surface water storage and irrigation scheme infrastructure in Vietnam are state owned and supply of irrigation water is provided without direct cost to farmers. Priorities raised in water sector reviews (Hirsch et al. 2005; Kellogg and Brown 2009; Can Tho University 2011) and during consultations indicate that the complex institutional arrangements for water resource governance are in need of further reform. Responsibility for implementing reforms is a matter for the Vietnamese government and recent amendments to the Law on Water Resources indicates that progress is being made in this area. While internal governance issues are mostly outside the scope of ACIAR's mission of supporting research for development, water resource policy intervention research may be appropriate under ACIAR's Land and Water Resources (LWR) and Agricultural Development Policy (ADP) programs. However, this may not be considered a high priority by ACIAR as Vietnam has historical and ongoing support in this area from large donors such as the World Bank, ADB and Danida (Denmark).

Any project focused on management of surface water resources for irrigation in SCC VN would be necessarily placed in a rice production setting. The reason for this is that around 90% of irrigation from surface water is used for year-round rice production (pers comm. Dao Ngoc Tuan, IWRP). Opportunities to improve efficiencies in the use of surface water for rice production are mostly at the irrigation scheme level. Currently excess water is released from reservoirs to allow for losses due to evaporation, leaking distribution channels and unused water released into fallow paddy land. These losses could be reduced by improving distribution networks. However, this is mainly an infrastructure upgrading issue rather than a researchable problem. In addition, Vietnamese planning agencies are focused on increasing reservoir capacity to negate water shortage risks. This approach is supported by large development donors, such as the ADB, providing loans and grants for developing and upgrading irrigation scheme infrastructure in Vietnam.

Downstream rice farmers located toward the end of irrigation channels would probably benefit most from supported research. When irrigation water supply requirements are underestimated and water released from reservoirs is inadequate, rice famers at the end of irrigation networks or rivers are affected by water shortages. Sea water intrusion into flood plains adjacent to tidal zones of lower river catchments is also a problem when water released from reservoirs is inadequate to maintain hydraulic pressure. Rice production issues are currently well supported by IRRI who conducts collaborative research in Vietnam and elsewhere to adapt rice production systems to reduce water consumption and to salinity. Outcomes from this and other research are available to SCC VN farmers but it is not clear whether DARD extension offices have been focussed on scaling out these.

Research to improve prediction of water demand and distribution by models and improve communication between water users, water resource managers and IMC's may benefit downstream rice farmers by identifying opportunities to improve the reliability of water supply. Evaluation of extension methodology, water distribution modelling and communication within the water sector are topics where there appears to be a need for improvement and that may be compatible with ACIAR's LWR program. The LWR program last invested directly in related work based in northern and southern Vietnam under

LWR1/1998/034, “System-wide water management in publicly managed irrigation schemes in Vietnam”, which completed in 2003.

7.2 Groundwater sustainability

As discussed in section 4, there are no agencies in Vietnam working with groundwater-dependent irrigated farming systems to regulate extraction of groundwater or to build farmers’ capacity in water and fertiliser use efficiency. SCC VN provincial agencies involved in groundwater resources at the implementation level are less resourced and have lower capacity than the national planning agencies. A significant structural shift in water governance, responsibilities of relevant government agencies, distribution of human capacity and funding arrangements in Vietnam is required to address these issues. Improvements may arise as a result of the current migration of responsibilities for water resources to MONRE. However, MONRE and its agencies would benefit from assistance in developing appropriate policy, regulatory and economic solutions for sustainable groundwater utilisation that is more inclusive of groundwater dependent agriculture. Such research would need to operate at national and provincial levels with strong support from the appropriate ministerial departments. At a policy intervention level, this issue could be referred to the International Food Policy Research Institute (IFPRI). Policy intervention research could also be taken up by ACIAR’s LWR and ADP programs but realisation of impacts for smallholder farmers from policy intervention research would occur over the longer term.

ACIAR SMCN 2003/035 recommended that future projects should address gaps in spatial information for groundwater resources in SCC VN and gaps in knowledge of the sustainable groundwater yield. During this SRA spatial information, groundwater potential estimates and planning documents and guidelines for exploitation of groundwater resources in SCC VN were identified (Section 5). However, it has only been since 2008 that momentum has accelerated in developing groundwater monitoring networks, updating related spatial information and developing and implementing groundwater management plans for provinces in SCC VN. While gaps remain, capacity is strong in this field, mainly at national and regional planning levels, and it appears that these gaps are being filled rapidly. In addition, UNESCO (in partnership with donors from Holland and Italy) and donors from Germany (BGR - Bundesanstalt für Geowissenschaften und Rohstoffe) are currently funding groundwater investigation projects in northern and southern provinces of SCC VN. Despite the level of activity in this area, there remain opportunities to contribute to this field through supporting groundwater hydrology investigations in central provinces such as Binh Dinh, where groundwater is critical to upland agriculture and there are gaps in groundwater resource knowledge. This work may be compatible with ACIAR’s LWR program, although detailed hydrogeology investigations will require significant investment which may be beyond budget limitations.

The volume of groundwater abstracted is known for major population centres in SCC VN (Section 5) but the volume of groundwater abstracted for agriculture and aquaculture, which are likely to be the largest users of groundwater, is mostly unknown. In addition, there does not appear to be reliable demand estimates for groundwater dependant agriculture and areas where groundwater shortages occur are not identified on maps. Landscape scale water balance studies would contribute to understanding whether current and projected groundwater utilisation for primary production is sustainable. As part of such studies areas where groundwater shortages and degradation are occurring could be identified and mapped. This would enable strategic prioritisation for targeting locations for on-farm water management training, farming system adaptation and development of irrigation water supply infrastructure. Related research could also determine the agro-economic value of groundwater dependent irrigation to the SCC VN region which may assist in attracting central government and foreign donor resources toward improving groundwater management in SCC VN. This work has a high level of compatibility with ACIAR’s LWR program.

Irrigation schemes in SCC VN are mainly established to service lowland rice with around 10% of water released used to irrigate other crops. There does not appear to have been studies that have assessed the feasibility of developing irrigation schemes to buffer against water shortages in groundwater dependant areas and improve production and facilitate development of agriculture in areas with limited or no access to water for irrigation. There may be an opportunity for ACIAR's LWR program to support irrigation demand and economic modelling to determine the feasibility of developing irrigation schemes for upland agriculture.

Farmers dependent on groundwater for irrigation in SCC VN are usually located in coastal and upland areas dominated by sandy soils. Predominant upland crops include cassava (108,900 ha), vegetables (66,500 ha), cashew (60,000 ha), peanut (32,100 ha), mango (12,100 ha) while maize and sugarcane are also grown. Contamination of groundwater used for irrigation is most likely in areas where there is intensive cropping on sands. High application rates of inorganic fertilisers, manures and pesticides and high infiltration rates and low nutrient holding capacity of the sandy soils, combine to increase risks of groundwater contamination. Declining groundwater quality is recognised as a significant issue in a number of coastal and midland districts. Preliminary results from groundwater sampling in Ninh Thuan province under SMCN 2003/035 and Phu Yen province under SMCN 2007/109 revealed several cases of very high nitrate levels (>50mg/L is common with >500 mg/L in some areas), well in excess of WHO guidelines for drinking water.

Current monitoring of groundwater quality focuses on groundwater used for urban and peri-urban consumption. In rural areas groundwater quality monitoring tends to be non-existent or rudimentary and ad hoc, unless a specific area is studied under an international donor project (e.g. Binh Thuan: Nguyen 2008; Ninh Thuan: current UNESCO project "Impacts of sea level rise by climate change on coastal zone and Islands in Central Part of Viet Nam"; Quang Ngai: current German donor project "Improvement of groundwater protection in Vietnam"). Some assessment and mapping of groundwater quality occurs as part of hydrogeological investigations by MONRE agencies (Figure 14). However, these data are mostly used for land use and groundwater exploitation planning purposes whereby groundwater quality is assessed based on its fitness for purpose. It is not clear how identification of groundwater quality problems is acted upon.

The existence of water quality issues indicates that there is a need to prioritise research to adapt and scale out integrated nutrient and water use management technologies. There are also strong prospects for this research to achieve short to medium term impacts on farmer livelihoods and improvement and protection of groundwater quality. Such research should be coupled with capacity building activities to support the development, testing and implementation of these technologies by research and extension personnel and groundwater-dependent farmers. This work would build on and amplify impacts from recent ACIAR investment in SCC VN and is compatible with ACIAR's SMCN program. Groundwater quality assessments and modelling are compatible with the LWR program.

7.3 Seawater intrusion and salinisation of coastal aquifers

Seawater intrusion is closely related to groundwater sustainability but it is a complex and specific issue that justifies treatment as a standalone priority. Concerns about coastal sea water intrusion into coastal aquifers were raised a number of times during consultations, with a general belief that the problem is wide spread in Vietnam and expected to worsen with increasing exploitation for domestic and industrial use, continued expansion of salt and shrimp farms and predicted sea level rise. When asked to nominate the distance of inland sea water intrusion along SCC VN rivers and through aquifers, answers given ranged from 100 m to 5 km for coastal aquifers and up to 20 km for rivers. The range quoted probably reflects location specific geological differences but also reflects a lack of monitoring of groundwater salinity at the provincial level.

During consultations Division 7 indicated that they held maps that marked boundaries of areas affected by salinity (only Ninh Thuan and Binh Thuan maps could be acquired during the term of this SRA; Figure 14). The existence of these maps indicates that some level of monitoring and reporting on salinity issues occurs, however, it appears that little of this data is published in Vietnamese or international research literature. Seawater intrusion is mentioned in IWRP and Division 8 water resource plans but few details are given. An 80 page 2008 DWRM report on Vietnam's Groundwater Resources (Dang, 2008) states that sea water intrusion is a significant issue, but again little detail is provided. The only mention of sea water intrusion in SCC VN is for Ninh Thuan where it is thought that sea water intrusion is caused by exploitation of groundwater for aquaculture.

Cases of sea water intrusion are commonly reported in Vietnamese media. On the 01st February 2007, the Thanh Nien newspaper quoted Mr Vo Anh Kiet, Director of the CMHF for SCC VN, as saying that seawater intrusion into coastal aquifers, especially adjacent to river mouths, between Da Nang and Binh Thuan province had been serious. Areas affected by seawater intrusion into coastal aquifers include: Da Nang 30 km^2; Quang Nam 100 km^2; Binh Dinh 130 km^2; Khanh Hoa 200 km^2 ; Ninh Thuan 130 km^2. Sea water intrusion into Han (Da Nang), Ve (Quang Ngai) and Ca Ty (Binh Thuan) rivers was reported as being 10 km to 25 km inland.

Vietnamese media reports for Binh Dinh province are supported by a Division 7 report (Vu Ngoc Tran n.d. "Some aspects on the pollution and salinity intrusion into groundwater in Binh Dinh") which indicated an area of 150 km^2 affected between Quy Nhon and Ha Than river and 20 km^2 near the gulf of Nuoc Ngot. The location and size of affected areas for Binh Dinh were further supported by a Binh Dinh Department of Science and Technology (DOST) media release reporting on outcomes from a sea water intrusion assessment carried out by Mr Vo Ngoc Anh (Vice-Director of the Meteor-Hydrology Centre for SCC VN). The DOST media release indicates that, in addition to the areas mentioned in the Division 7 report, sea water intrusion also affects land adjacent to Tra O lagoon 28 km^2 and Lai Giang delta 37.9 km^2. However, Mr Anh contradicted previous reports by claiming that the current area affected by sea water intrusion in Binh Dinh has been unchanged in the last 100 years. However, significantly Mr Anh does not refer to historical data to support his claim and the statement was made in defence of the aquaculture industry.

There are a few specific areas under a UNESCO funded project, Ninh Hai to An Hai districts in Ninh Thuan province, for which there have been recent seawater intrusion / groundwater salinity surveys. Ninh Hai district was also the subject for basic groundwater salinity surveys under SMCN 2003/035 in 2009 and 2010 at which time measured EC levels averaged 5.6 dS/m (n=31) but were as high as 13 dS/m. The project leaders for the UNESCO project were contacted during the term of this SRA. This project will complete in 2014 but no data has been released as yet. The UNESCO project is expected to partially fill a gap in understanding the extent and causes of groundwater salinity in Ninh Thuan province. However, there remain opportunities to support ongoing monitoring, hydrological and salinity modelling and to conduct groundwater and community surveys to determine the status of coastal aquifer salinity in SCC VN provinces where data may not exist. Basic observational studies related to this issue could be undertaken within ACIAR's SMCN program but more in-depth research is best positioned under the LWR program.

During consultations the Ninh Thuan DARD stated that adaptation to groundwater salinity was a key priority for districts where vegetables are grown on the coastal fringe of Ninh Thuan. Vegetables are grown on around 450 ha in Ninh Hai, 140 ha in Van Hai and 150 ha in An Hai. Deep sands are dominant in these areas. Water and nutrient holding

BẢN ĐỒ CHẤT LƯỢNG NƯỚC DƯỚI ĐẤT VÙNG CỰC NAM TRUNG BỘ

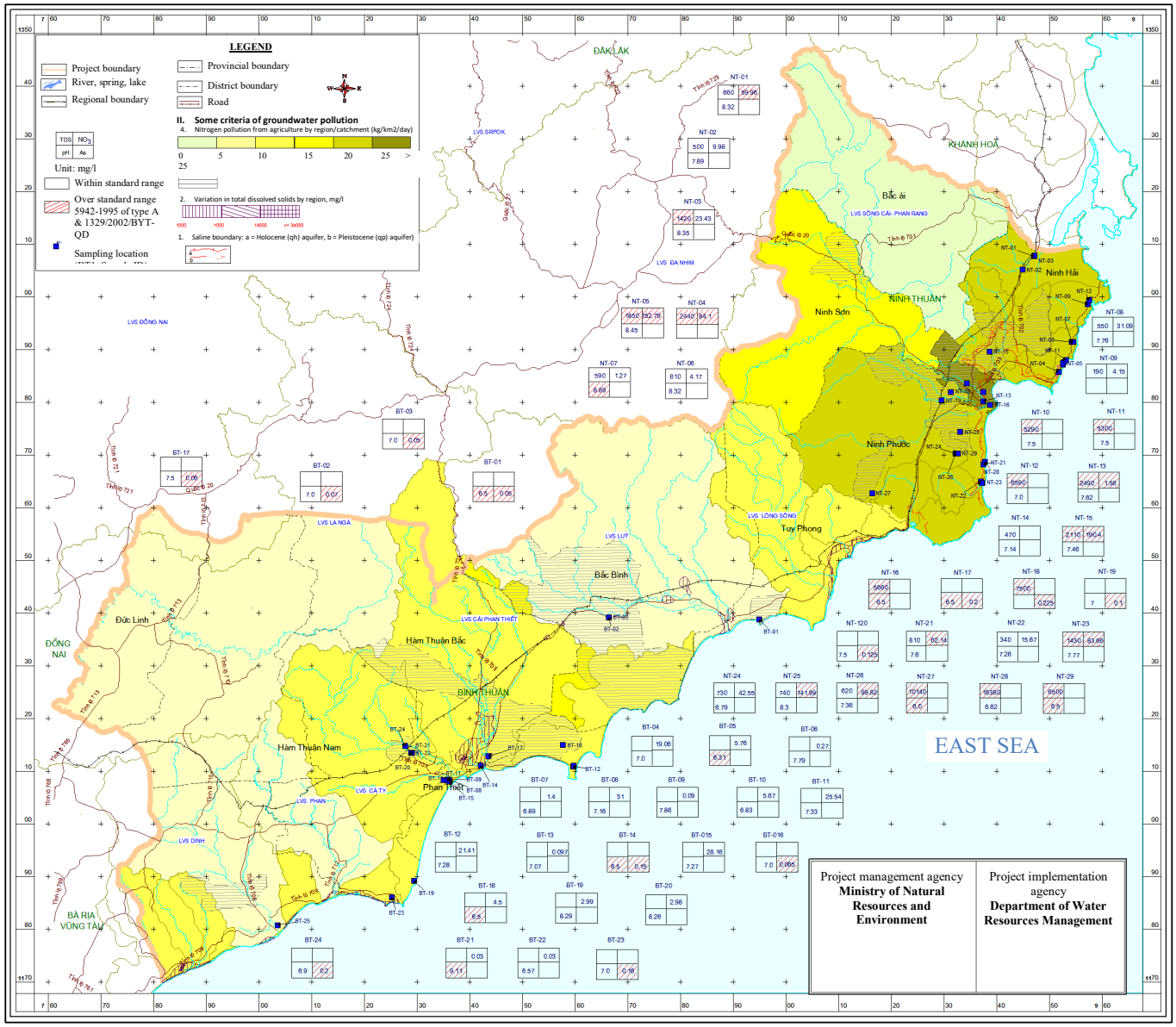

Figure 14. Groundwater quality map for Ninh Thuan and Binh Thuan provinces.

capacity are low while infiltration rates are high. Consequently, these areas also tend to have high rates of fertiliser applied which further complicates the salinity issue by loading the groundwater with nitrates and other contaminants. The current situation presents challenges as sea water intrusion is not easily reversed, but there are prospects for ACIAR's SMCN program to support research to adapt irrigation and fertiliser practices and cropping systems to reduce the impact of saline water and soil on farmer livelihoods. With sea water intrusion expected to worsen in the future, there is a clear need to develop adaptation strategies in preparation. Work undertaken in Ninh Thuan province would provide a case study for other areas affected by sea water intrusion and to promote on-farm water use efficiency practices to prevent overexploitation of vulnerable coastal aquifers.

One such area is Phu Yen, where there are 1,150 ha (25% of Phu Yen's vegetable production area) of vegetables produced on coastal sands with plans to nearly double this area by 2020. During consultations the Phu Yen DARD nominated sustainable vegetable production on coastal sands as a key priority for Phu Yen. This was nominated as a priority as vegetable production is important to food security in Phu Yen. There are opportunities to improve the income of small area farmers by growing higher value crops but there is also a need to improve the productivity of existing vegetable crops by developing solutions to overcome soil constraints and seasonal water availability. The status of groundwater salinity and quality is mostly unknown in areas where vegetables are grown on sandy soil and the extent to which groundwater quality issues may be affecting productivity is unknown. Work to document soil and groundwater quality issues associated with this priority commenced under SMCN 2007/109 C2 in An Chan commune, Tuy An district. There is an opportunity for ACIAR's LWR Program to support project activities to extend groundwater surveys to the three main coastal vegetable districts of Tuy Hoa, Tuy An and Dong Hoa in Phu Yen and for the SMCN program to support applied research to identify solutions to soil constraints.

7.4 Soil constraints associated with SCC VN sands

ACIAR projects SMCN 2003/035 and SMCN 2007/109 C2 made a significant contribution to understanding constraints associated with sands in SCC VN and toward developing strategies to ameliorate these. Through reviewing literature (Hoang et al. 2010), application of SCAMP (Phan 2011a,b,c), and nutrient omission experiments (Hoang et al. 2012) constraints in SCC VN sands were identified as: low organic matter / carbon; acidity; alkalinity; low water and nutrient holding capacity; high infiltration and nutrient leaching; hardpan formation (depending on landuse history); N, P, K, S, Cu, B, Zn and Mo deficiencies.

Nutrient omission experiments with soil-applied K and S and soil- or foliar-applied micro-nutrients demonstrated that correction of nutrient deficiencies can result in significant productivity gains (20% - 30%) in annual crops, such as peanut, and in tree crops including cashew and mango grown in SCC VN sands. However, fertiliser manufacturers in Vietnam currently lack technology to produce slow release, complete and micro-nutrient fertilisers and so availability of these types of fertilisers is very limited. This meant that several of the micro-nutrients used for the omission experiments had to be obtained from pharmaceutical supplements. Consequently, there remains a need to research practical and affordable solutions that farmers can utilise to improve fertiliser use efficiency and correct nutrient deficiencies in SCC VN sands.

Collaborating with fertiliser manufacturers in Vietnam to develop technologies to produce high quality slow release, complete and micro-nutrient fertiliser products will increase their availability. Providing guidelines and education to extensionists and farmers will aid in creating favorable market conditions to motivate production and supply of slow release, complete and micro-nutrient fertilisers. However, it will require sustained co-investment in longer term research to prove-up fertiliser combinations and application rates and

communication to facilitate the development of a supply chain. A three to four year ACIAR project can initiate this process but delivery of short to medium term on-farm impacts requires applied research to identify other options that can be readily integrated into existing farming systems.

Utilisation of organic soil amendments can increase soil water holding capacity, improve soil physical parameters and ameliorate soil nutrient deficiencies (Lal, 2006). Previous SCC VN ACIAR projects demonstrated the potential for rice husk biochar as an economically effective soil amendment to improve cashew, mango and peanut productivity in sands. The rice husk biochar effect was greatest when combined with manure and NPK. This may have occurred due to rice husk biochar increasing soil carbon, soil water (marginally) and nutrient retention and by slow release of P and K (Keen et al. unpublished). Improved storage and composting methods for preparing cattle manure soil amendments also improved peanut productivity (Hoang et al. 2012). Manure adds limited N and P to the soil unless rates are high but K supply may be significant and manure can also be a source of Cu.

The most appropriate soil amendments for a given farmer will be those that are best suited to the farmer's context. As such a variety of sources of soil amendments need to be evaluated based on whether the material is readily available and economical and depending on the intended purpose e.g. supply of soil organic carbon or to ameliorate a specific constraint such as a nutrient deficiency.

In parts of Central Vietnam aquatic plants are used by farmers as a low cost amendment for sands. Vermicomposting of water hyacinth with pig manure at a ratio of 1:3 was found to have potential for use as a high N soil amendment (Zirbes et al. 2011). The fertiliser capacity of 12 macrophytes and five algae from Thua Thien Hue province was studied by Ancion et al. (2009) and Neve et al. (2009). Element concentrations (% dry matter) were: N 1.0 to 3.5; P 0.08 to 0.45; K 1.0 to 4.2; Mg 0.3 to 1.4; Ca 0.7 to 2.8; Na 0.7 to 7.6. Surveys conducted under SMCN 2003/035 and SMCN 2007/109 did not identify any SCC VN farmers who utilise aquatic plants and members of the SRA team have not observed the use or study of aquatic plants as a soil amendment in SCC VN provinces south of Quang Nam. Positive results from previous studies and an apparent absence of the practice in much of SCC VN, highlights an opportunity to evaluate the macro- and micro-nutrient value of local aquatic plants.

In areas where utilisation of aquatic plants is not practical alternative soil amendment solutions are needed. Other locally available materials with prospects for utilisation as soil organic amendments include agricultural processing residues such as peanut and coconut husks. There does not appear to be statistics for the quantity of agricultural processing residues for SCC VN. The quantities are likely to be substantial but a resource assessment is needed to determine the supply potential of the various recyclable organics. As part of a resource assessment the nutrient value of each material should be assessed with the final outcome being identification of "best bet" organic materials for utilisation as soil amendments.

Municipal putrescible wastes are another potential source for soil organic amendments. Collection, composting and reuse of municipal putrescible waste is emerging near larger urban centers in parts of SCC VN (pers. comm. Hoang Thi Thai Hoa; HUAF). While recycled organic municipal waste can be a beneficial soil amendment, contamination with plastic, glass, heavy metals and toxic compounds can limit its use in agriculture. Municipal waste should be included in an organic resource assessment but contaminant risks should also be investigated. In addition, an opportunity exists for ACIAR projects to assist with developing guidelines or standards for production and utilisation of recycled organics to manage contaminant risks for recycled organics intended for application to agricultural land in SCC VN.

Bentonite clay additions have been shown to restore the productive capacity of degraded soils within a short time and with long lasting effects (Berthelsen et al. 2005). As such addition of clay to sands can provide an alternative or complementary practice to soil

organic amendments. Clay additions to sands was investigated under SMCN 2007/109 for improving water and nutrient retention for vegetable production in An Chan commune, Phu Yen province and for pastures in Western Australia. Work in Western Australia (Hall et al. 2011) indicated that clay soil amendments may protect organic matter in sands, thus aiding to increase organic matter over time. Spading of sands with subsoil clay applied at 200 t/ha to 300 t/ha (5% to 6% v/v) almost doubled dry matter yield of a serradella pasture. Laboratory experiments indicated that Fe oxyhydroxides, associated with the clay, increased P sorption which in turn reduced P leaching. In the Phu Yen province field experiments bentonite clay applied at 100 t/ha and mixed to 20 cm depth increased pumpkin and onion yields, increased soil moisture holding capacity, raised soil pH by 1.1 units and increased CEC four fold. The bentonite clay effect was further enhanced when combined with biochar.

Bentonite mines in Phu Yen province make this a readily available source of clay for Phu Yen and neighboring provinces. Should bentonite not be practical (cost of transport may be prohibitive for some farmers in Phu Yen and other SCC VN provinces) for a particular farmer, then clay can be sourced from subsoils on the farm or from close-by clay deposits and alluvial soils. For example, in parts of Central Vietnam farmers are reported to be adding ferralsol soil to sands to improve the productivity of vegetable crops. Kaolinite is the predominant 1:1 mineral clay type of ferralsols (FAO classification). The dominate soil types in SCC VN are Acrisols and Aerensols (FAO classification) and kaolin (kaolinite and halloysite) and siliceous quartz are the predominant clay minerals associated with these (Nguyen et al. 2008; Hoang et al. 2009). The Acrisol and Aerensol soils also contain smaller amounts of the 2:1 type clay minerals mica, illite, vermiculite, chlorite and mixed layer combinations (Nguyen et al. 2008). Addition of these local clays to sands in SCC VN is likely to improve soil water and nutrient retention and crop performance and to have long lasting benefits for farm productivity but applied research is needed to confirm this.

Research work focused on managing soil constraints associated with SCC VN sands is most appropriately positioned within ACIAR's SMCN program. However, collaboration between SMCN and LWR programs would also be appropriate given that an integrated soil nutrient and water use management package involving organic and clay soil amendments, improved fertiliser management and efficient use of water will have positive implications for groundwater sustainability.

7.5 Considerations for approaches to community impact delivery

Between 2007 and 2012 ACIAR investment in SCC VN via SMCN 2003/035 and SMCN 2007/109 delivered a number of promising technologies suitable for on-farm adoption. Many of these have been absorbed by farmers who were involved in participatory research, capacity building and communication activities during the project but more wide spread adoption has been slower to occur. The reason for this appears to be inadequate provincial and national level funding allocation within Vietnam to mount and sustain scale-out programs beyond the life of the project.

Nationally funded scale out[1] of specific agricultural research outcomes in Vietnam involves a formal evaluation and approval process. Local DARD extension officers can scale up[2] simple practice changes within their province through integrating research outcomes into existing communication and dissemination. However, to secure funding to support more widespread scale out of significant technology or more complex practice

[1] Scale out defined as "the geographical spread of a technology, practice or systems change over time" (Millar and Connell , 2010).

[2] Scale up defined as "expanding beneficial institutional and capacity building practices within and across organisations and networks at local to international levels" (Pachico and Fujisaka, 2004 in Millar and Connell, 2010).

and system change requires approval at a national and provincial level. This process has particular relevance for initiatives such as releasing new crop varieties and for disseminating guidelines for complete fertiliser management for a specific crop such as peanuts. Each province has guidelines outlining requirements for applying for scale out funding approval. Much effort is required to prove-up the respective technology or practice or system change before applying for approval.

The most important component of the process is large area (e.g. several hectares for a new rice variety) “model” demonstrations. The farmers who are involved need to approve the model as does PPC. A national science committee (under MARD and MOSTE) reviews data supporting the model, approves the technology or practice change and recommends budget allocation to support scale out activities. Budget allocation is usually to the province in which the demonstration trial was carried out. If scale out was successful within the province, financial and operative support may then be extended to other provinces.

While there are a number of options for scaling out project outcomes, maximising impact delivery from ACIAR projects in SCC VN requires engagement in Vietnam’s formal scale out approval process. As such new ACIAR projects should allocate resources to support demonstrations that will be used to seek approval and financial support for sustained scale out from Vietnam’s central government. Demonstrations should aim to promote technology, practice and system changes identified as having high impact potential from previous and future ACIAR projects. However, reliance should not be placed solely on this process. New projects will also need to consider alternative pathways to deliver impacts.

Traditional approaches to extension in Vietnam involve farmer field days and dissemination of information through DARD extension offices and via television stations dedicated to current affairs in agriculture. There is a need to evaluate the effectiveness of current mainstream approaches against alternative methods. New ACIAR projects in SCC VN should give consideration to assisting DARD extension offices develop and evaluate specific farmer capacity building programs. For example, SMCN 2003/035 introduced the NSW DPI “WaterWise” training program to research and extension personnel in Vietnam and there is now an opportunity to further adapt and evaluate this training package for delivery to SCC VN famers. Farmer field schools are another effective extension tool (Van den Ban and Samantra, 2006) that could be used for providing farmers with practical training in topics such as soil management and crop nutrition. However, delivery of these formalised packages would usually be through DARDs which requires ongoing government, or possibly external, funding to sustain activities beyond the life of an ACIAR project.

Previous ACIAR projects in SCC VN focused on building institutional partnerships, with expectations that institutional partners would engage with end users during and after the project. This strategy has been effective but, as discussed above, with limitations. An alternative approach for future SCC VN ACIAR projects could be to also have direct engagement with end user networks such as the Vietnam Farmer’s Association, Vietnam Women’s Union (VWU-Department of Ethnic and Religious Affairs) and commune level farmer groups. Taking this pathway lessens dependence on Vietnamese government agencies and funding from central and provincial governments.

Networks associated with the VWU branch across Vietnamese society at national, provincial, district and commune levels. Utilising the VWU’s established networks may be an effective strategy for disseminating information. VWU also have strong linkages with NGOs such as CARE which may improve prospects for securing ongoing external support for implementing training models evaluated under future SCC VN ACIAR projects. Utilising commune level farmer groups may also be another strategy to facilitate “spontaneous scale out” (Millar and Connel, 2010). Training extension mentors and commune leaders to conduct farmer to farmer training and organising cross visits and study tours are approaches that have proven effective elsewhere (Millar and Connel, 2010). Another economical approach to dissemination could be to develop training videos

suitable for broadcasting on Vietnam's agricultural television stations and for multi-media distribution.

8 Conclusions and recommendations

8.1 Conclusions

This SRA project has facilitated a clearer understanding of water resource information status, governance arrangements and current management in Vietnam and identified water resource research and implementation priorities for water, soil and cropping systems in SCC VN. Vietnam's water resources policy, law and institutional arrangements have a history of complexity and fragmentation with surface and groundwater resources divided between two ministries. Progress is being made with recent changes to the Law on Water Resources which aim to consolidate management of water resources under MONRE. However, as in the past the focus remains on national level policy and institutional arrangements with human capacity and resource allocation concentrated in national planning institutes. Resource allocation and human capacity diminishes at and below provincial implementation levels. At the end of the line are smallholder farmers.

Farmers reliant on surface water, mostly lowland rice farmers, appear to be well serviced under MARD. However, there are no agencies or groups working with groundwater dependent farmers to regulate or monitor groundwater use or educate them on managing irrigation and nutrients for efficiency and resource protection. ACIAR's focus on smallholder farmers puts ACIAR projects in prime position to facilitate improved interaction between MARD and MONRE agencies and groundwater dependant farmers. This interaction will become more important with MONRE recently taking on responsibility for water resources management but with a mandate that mostly distances MONRE agencies from agriculture.

When the project team planned this SRA, expectations were that information, maps and plans for sustainable groundwater utilisation in SCC VN would be few. The amount of information from hydrogeological investigations discovered has far exceeded expectations. However, language, remoteness and logistical constraints meant that not all of this information could be accessed and evaluated during the term of this SRA. As such there will be a need to extend information review activities into new ACIAR water resources related projects in SCC VN. In particular, cartographic resources and groundwater exploitation plans held by Division 7 should be interrogated in greater detail.

Much of the information discovered during the SRA is in province-bounded planning documents which describe the hydrogeological context of the various aquifers, outline plans for capital works and provide guidelines for dynamic groundwater reserves and sustainable yield. However, knowledge on water use appears to be a significant gap in understanding the regional water balance. Without monitoring or regulation of agricultural and aquaculture groundwater users the sustainability of current levels of groundwater abstraction cannot be evaluated accurately. The existence of this gap indicates an opportunity for new water resource-related ACIAR projects in SCC VN to model this component to complete water balance knowledge at a regional scale.

Declining groundwater quality was identified as an issue associated with a number of communities reliant on coastal aquifers in SCC VN. While basic water quality assessments (pH, TDS, NO_3, As) are undertaken for hydrogeological surveys, water quality monitoring is rarely undertaken outside urban areas unless DONRE are called to investigate a contamination event. There is a need to facilitate greater recognition of the need for groundwater quality monitoring in rural areas. Division 7 and provincial DONREs in SCC VN are the appropriate entities to undertake groundwater quality monitoring. DARDs and DONREs are the most appropriate entities to take action on the results. Improved knowledge of groundwater quality would enable DARDs and DONREs to target rural communities to assist them in improving on-farm irrigation and nutrient management.

Seawater intrusion into coastal aquifers in SCC VN has occurred in a number of locations with affected areas totalling 750 km^2. Farming continues in many of these areas but the impact on crop productivity is not known. While agriculture continues on salt affected land, farmers need solutions that enable them to adapt their farming systems. Solutions are also needed to improve management of groundwater abstraction to reduce risks of over extraction leading to future seawater intrusion events. This applies to affected areas such Ninh Hai district in Ninh Thuan and unaffected but at-risk area such as the coastal sandy zone of Phu Yen, where there are plans to increase the area of land utilised for vegetable production.

Constraints associated with the sandy soils of SCC VN contribute toward water quality issues. Farmers have a tendency toward excessive irrigation and fertiliser use to compensate for the low water and nutrient holding capacity of the sands. This leads to nutrients leaching to the groundwater with nutrient losses also equating to economic losses to the farmer. Organic and clay soil amendments can ameliorate these constraints. These technologies have been tested before but local resources need validating within the SCC VN context. NPK fertilisers are the most commonly used nutrients applied to crops in SCC VN. When guideline NPK rates do not deliver the desired results farmers are often convinced to apply more NPK fertiliser, not realising that their problems are related to sulphur or micro-nutrient deficiencies. SMCN 2007/109 demonstrated significant productivity gains from treating sulphur and micro-nutrient deficiencies. However, there remains a need to evaluate cost effective solutions to correcting nutrient deficiencies.

ASISOV's capacity to undertake field research in irrigation, soil and fertiliser management and crop science has strengthened considerably since collaboration with ACIAR commenced in 2007 under SMCN 2003/035. Recent ADB investment has furnished ASISOV's laboratories with modern and advanced scientific instruments which has enhanced their capability in soil, water, plant and microbiological analyses and controlled environment research. However, ASISOV's laboratories would benefit greatly from implementation of a Quality Assurance system via accreditation under the Vietnam Laboratory Accreditation Scheme (VLAS).

Developing capacity building programs for famers needs to be given greater attention under future SCC VN ACIAR projects. To achieve this DARDs extension offices first need to be the target of structured capacity building activities. Future ACIAR projects need to allocate time toward understanding extension approaches in SCC VN and evaluating current and alternative approaches for effective scale up and scale out of project outcomes. Proving up technologies and initiatives via pilot scale out and field demonstrations involving a number of farmers are critical to securing central and provincial government approval and funding to support geographically broad scale out. As such future ACIAR projects should support these.

As has been outlined in this SRA report, there is considerable scope for ACIAR projects to contribute to sustainable groundwater utilisation, soil and crop management and smallholder farmer livelihoods in SCC VN. Future SCC VN ACIAR projects need to balance research and scale out activities to ensure that impacts are fully realised across all levels of research, extension and the farming community in SCC VN.

8.2 Opportunities

Opportunities for ACIAR's LWR and ADP programs

- Support projects on policy intervention to improve regulation and funding for services provide to groundwater dependant farmers.

Opportunities for ACIAR's LWR program

- Support landscape scale water balance studies with the purpose of understanding whether current and projected groundwater utilisation for primary production in SCC VN is sustainable.
- Facilitate implementation of coordinated programs for water quality monitoring, modelling and mapping in targeted rural areas within SCC VN.
- Support hydrological and salinity modelling and conduct groundwater and community surveys to determine the status of coastal aquifer salinity in SCC VN districts were data does not exist.
- Improve extension and communication to improve outcomes for groundwater dependant farmers.
- Support groundwater hydrology investigations in central provinces where there are gaps in groundwater resource knowledge.
- Support economic modelling to determine the feasibility of developing irrigation schemes to buffer against water shortages in groundwater dependant areas and improve production and facilitate development of agriculture in areas with limited or no access to water for irrigation.
- Improve predictive water demand and distribution modelling and improve communication between surface water users, water resource managers and IMC's.

Opportunities for ACIAR's SMCN program

- Support research to evaluate practical and affordable solutions to improve fertiliser use efficiency and correct nutrient deficiencies in SCC VN sands.
- Support research that evaluates local organic resources and clays as soil amendments to ameliorate site specific soil constraints.
- Support research to adapt integrated water use and nutrient management technologies in SCC VN.
- Support research to adapt irrigation and fertiliser practices and cropping systems to reduce the impact of saline water and soil on farmer livelihoods.
- Implement capacity building activities to support the development, testing and implementation of integrated nutrient and water use management technologies by research and extension personnel and groundwater-dependent farmers.
- Facilitate development of guidelines for production and use of recycled organics in SCCN agriculture.

9 Framework for a new ACIAR project

A key purpose for this SRA was to scope opportunities for a new ACIAR project to contribute toward soil and water resources research in SCC VN under ACIAR's SMCN program. The following framework was developed for a new project based on an indicative budget of $AUD 1 million. The preliminary proposal for this new project was approved by ACIAR through an in-house review process in March 2013. An additional $250,000 was allocated to the project from ACIAR's LWR program, bringing the total indicative budget to $AUD 1.25 million over 4 years. The following sections present an updated summary of the proposal developed under this SRA for SMCN 2012/069 (Appendix 3).

The issue

SMCN 20012/069 focuses on groundwater-dependent smallholder farming systems in South Central Coastal Vietnam (SCC VN). The groundwater resource in SCC VN is vulnerable to overexploitation, contamination due to nutrient (>50 mg $N0_3$-/L is common in many areas) and pesticide leaching and salinisation in near coastal areas (750 km^2 total affected area in Quang Nam, Binh Dinh, Khan Hoa, Ninh Thuan and Binh Thuan). Improving knowledge and awareness of groundwater sustainability issues at planning and regulatory levels and on-farm via improving water and fertiliser use efficiency, are fundamental to achieving sustainable groundwater management

The project also focuses on improving the productivity and sustainable management of soil which are common priorities for SCC VN, New South Wales and Western Australia. Biophysical constraints, including >330,000 ha of low fertility sands and climatic extremes, present challenges for agricultural production and poverty alleviation in SCC VN. Groundwater dependent farming systems are mostly established on sands and are frequently affected by water shortages during the 7 to 9 month dry season. Predominant groundwater-dependant crops are cashew (60,000 ha), mango (12,100 ha), peanut (32,100 ha), cassava (108,900 ha) and vegetables (66,500 ha). Previous value chain studies funded by ACIAR suggest all these crops have market potential in SCC VN. However, crop productivity is constrained by soil physical limitations and nutrient deficiencies associated with the sands**.** These soils pose major challenges for efficient water and nutrient management. Integrated irrigation and fertiliser management and organic and other soil amendments are key to improving their productive capacity.

Priorities and strategies for the project were developed through consultations, conducted under an ACIAR commissioned small research activity (SRA), with Vietnamese research, planning and extension agencies (Appendix 1). The SRA examined related research conducted in the region by ACIAR and other donors and identified research gaps that align with ACIAR's country priorities for Vietnam, where Australian agriculture technical skills have a clear ability to assist.

Research questions

Our research questions are:

- Is groundwater utilisation for agricultural production in SCC VN sustainable?
- What technologies and practices can be utilised by groundwater dependent farmers in SCC VN to improve on-farm water use efficiency and reduce nutrient losses?
- What are the most practical and cost effective solutions to overcome soil constraints and alleviate soil nutrient deficiencies?

- What solutions can be implemented to adapt affected farming systems to saline irrigation water?

Objectives and outputs

This project contributes toward the goal of improving livelihoods for smallholder farmers in SCC VN and for sustainable soil management in WA and NSW. The specific aim for the project is to identify and facilitate adoption of technologies and strategies for sustainable groundwater utilisation and to develop options for improving the productivity of soils in SCC VN, WA and NSW by:

1. Assessing status of groundwater utilisation and quality in targeted areas within SCC VN.
2. Evaluating methods to improve on-farm water use efficiency and evaluating soil amendments to overcome soil constraints and reduce nutrient leaching.
3. Evaluating solutions to adapt affected farming systems to saline irrigation water.
4. Facilitating scale out and increasing the capacity of research and extension personnel and farmers in water use, soil and nutrient management in SCC VN.

The primary outputs are expected to be:

- Integrated water and nutrient management training modules for Vietnamese farmers.
- Soil amendment technologies for overcoming soil constraints to increase productivity of sands.
- Guidelines for managing soil nutrient deficiencies in sands.
- Technologies for adapting affected farming systems to saline irrigation water.
- Communications delivered to next-users to encourage adoption of promising technologies and practices and to secure central government approval and funding for expanding scale out programs.
- Communications delivered to influence policy and initiatives aimed at improving groundwater sustainability in SCC VN.

Adoption pathways and dissemination of outputs

Outputs of scientific significance will be disseminated through Vietnamese and international journals and conference proceedings. Biannual workshops will be held with key institutional stakeholders to communicate up-to-date findings of project outputs.

The project will support several demonstrations of promising technologies and practices. The demonstrations will also function as a training resource for extension personnel and for farmer to farmer visits. Specific purpose extension television stations will be utilised to broadcast training videos filmed at demonstration sites (subject to Vietnamese government approval). Activities will also be established to disseminate information to farmers through farmers unions and womens unions and informal end-user networks.

Project benefits

Integration of water use and nutrient management will increase the economic efficiency of water and fertiliser use and increase crop productivity. Based on outcomes from previous ACIAR projects in SCC VN, economic benefits are potentially within the range of >$20 million per year in value to peanut farmers in SCC VN.

Improving integrated water, soil and nutrient management will lead to more efficient utilisation of groundwater and assist in improving groundwater quality. Adoption of

balanced nutrition (S and micronutrients) and organic soil amendments could generate >$60 million per year in value to peanut, cashew and mango farmers in SCC VN.

Actions resulting from communication of groundwater quality issues to Vietnamese and international organisations has potential to stimulate initiatives that deliver community health benefits.

Partnerships

The NSW Department of Primary Industries will be the commissioned organisation. Dr Brad Keen (Project Leader) has expertise in soil and irrigation research and has been working under ACIAR projects with partners in SCC VN since 2007. Dr Keen will be supported by Dr Peter Slavich (Southern Cross University). Dr Slavich has expertise in soil and water management and utilisation of saline groundwater for irrigation. Prof. Richard Richard Bell (Murdoch University) is a specialist in soil fertility and land management with extensive experience in Australia and developing countries including Vietnam. Dr Slavich and Prof. Bell led previous ACIAR projects in SCC VN and their involvement will provide continuity in research leadership. Prof. Okke Batelaan (Flinders University) will also join the project team. Prof. Batelaan is a leading international hydro-geologist with 10 years of involvement in collaborative research in Vietnam.

The project builds on relationships established under previous ACIAR projects in SCC VN. Existing partnerships will be strengthened, particularly with ASISOV, provincial Departments of Agricultural and Rural Development (DARD), Institute of Agricultural Science for Southern Vietnam (IAS), Hue University (HUAF), Nong Lam University (NLU) and new partnerships will be formed with the central Vietnam division of the Centre for Water Resource Planning and Investigation (Division 7) and provincial Departments of Natural Resources and Environment (DONRE).

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