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Final report

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prepared by	• Dr Paul Pavelic, Mr Mathieu Viossanges, Dr Oulavanh Keovilignavong & Mr Santi Keonouchanh (IWMI) • Prof Okke Batelaan & Dr Eddie W. Banks (Flinders University / NCGRT) • Dr Michael Hatch (University of Adelaide) • Dr Thavone Inthavong (NAFRI)
co-authors/ contributors/ collaborators	• Mr Khantong Soithivong & Mr Ounakone Xayviliya (DWR) • Mr Anousone Khounsombut & Mr Sathathep Thammachak (DOI) • Dr Sinxay Vongphachanh (NUOL-FWR) • Dr Sounthone Singsoupho (NUOL-FS) • Ms Poupey Keovongdy (IWMI)
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1 Acknowledgments

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2 Executive summary

Groundwater resources offer significant opportunities for Lao smallholder farmers to access climate-resilient irrigation water supplies for the intensification of agriculture. Use of groundwater by smallholder farmers for the production of various fruits and vegetables appears to be growing nationally. This research aims to identify & prioritize opportunities for sustainable development of groundwater resources with specific focus on the lowland plains and upland plateaus of Laos. It addresses this aim through three key objectives:

1. Establish the potential to develop groundwater for irrigation in key hydrogeological settings in Southern Laos;

2. Assess the opportunities that solar-powered pumping technologies may provide smallholder farmers seeking to engage in more profitable, market-oriented agriculture; and

3. Enhance the capacity of current and emerging groundwater professionals in Laos.

Two areas with promising aquifer development potential were selected in Southern Laos: a drought-prone lowland area underlain by sandstone aquifers in Savannakhet province (Outhomphone district); and a wetter, upland basaltic area on the Bolaven Plateau (Pakxong district). For the first objective, a preliminary hydrogeological assessment has been undertaken based on the collation and analysis of existing (limited) data supplemented by data from a network of around 40 to 50 monitoring wells in each district and other hydrogeological measurements collected during two field campaigns. For the second objective, the opportunities for solar-powered groundwater pumping to provide an alternative to conventional grid electricity or fuel pumps has been explored through policy analysis and the evaluation of a demonstration project as well as actual field operations. The third and final objective involved a cross-cutting effort to enhance capacity of current or emerging groundwater professionals.

For Outhoumphone, where the need for dry season access to reliable groundwater sources is high, the sandstone aquifers present are likely sufficiently replenished but inadequately productive to provide a substantial resource for expanding dry season irrigation. Drillers in the area report well instability, saline water and drilling failure as common technical challenges. With adequate field investigations these challenges may be overcome and supplies for commercial agriculture could become feasible.

For Pakxong, where the basaltic aquifers are more productive and reliable, field observations show that more entrepreneurial farmers have already started to develop groundwater for high value commercial crops. There is clear scope to expand irrigation development. Drillers report high success rates for wells and this is supported by the aquifer testing undertaken during this research.

Even though policies on solar technologies in agriculture are limited, the solar industry appears to be expanding rapidly, with over twenty solar companies based in Laos; most of which are also servicing the agricultural sector. A demonstration site operated by the National Agriculture and Forestry Research Institute in Vientiane Capital provides first-hand experience of solar pumping and data is emerging on its functioning and performance. Rapid assessments of six solar pumping sites on the Vientiane Plain show that better-off farmers and investors with the means to afford the upfront capital cost are accessing water on demand at effectively little or no marginal cost. Although the situation is evolving rapidly, solar water pumping for agriculture still remains an emerging technology in Laos and hence the long term technical performance, economic viability and potential impacts on the groundwater resources remain entirely unanswered at the present time.

A one-week hydro-geophysics training course took place in Pakxong in November 2020 that involved 14 attendees from government agencies and the national university. Training was provided in fieldwork and analysis in new techniques to investigate groundwater using geophysical equipment, site wells, drilling and aquifer testing and aquifer conceptualization. In-situ guidance was provided by in-country team members supported by higher level oversight provided remotely by trainers based in Australia due to travel restrictions associated with COVID-19. The project has also enabled 5 Bachelor, Master and Doctorate students to undertake thesis research.

This project has provided valuable scientific and capacity enhancement. Expansion of this research would also hold considerable potential to support improved water resource, agriculture and energy policies. In keeping with the current country priorities for Lao PDR, ACIAR should continue to prioritize groundwater-related research in Laos through its commitment to enhancing climate resilience and approaches to climate change adaptation for smallholder farmers.

Further research in areas detailed in this report, would provide an informed basis for climate-resilient fruit and vegetable production, enabling sustainable pathways to enhance nutrition and livelihoods in rural areas. Further, it would enable a sound basis for establishing the opportunities for sustainable use of groundwater resources in the face of mounting pressures from climate change and emerging developments such as the growth of solar water pumping which has the potential to greatly accelerate groundwater development in Laos, mirroring trends observed in many other countries and regions.

3 Background

The lowlands of Laos, which extend across a 1,000 km tract from Xayabouly province in the north to Champasak province in the south, support a population of around five million people or 70% of the national population. These lowland areas, together with the major upland plains, including the Bolaven Plateau, have the greatest potential for the expansion of market--oriented agriculture as recognized in the Lao Agricultural Development Strategy (MAF 2015). Access to on-farm irrigation water is of critical importance for expanding market-oriented agriculture and for climate change adaptation as these contrasting landscapes are inherently drought-prone due to regular occurrences of poor monsoonal rainfall and extended dry spells. Enhancing resilience of farming systems to climate will become increasingly important as the effects of climate change worsen in coming years (WB & GFDRR 2011).

At the national level, only around 20% of farming households have their own irrigation infrastructure or can access irrigation services (MAF 2012). Small-scale farmer-driven irrigation is becoming increasingly commonplace to provide flexibility to regulate water supply on demand at the field level. Farmers across the country are moving towards groundwater-based irrigation for dry season cash cropping, livestock production and aquaculture; and to protect against dry spells during the monsoon (Pavelic *et al.* 2014).

Groundwater potentially offers Lao smallholder farmers scope to enhance and regulate water supply on their farms to enable diversification beyond wet season paddy farming to improve their livelihoods and resilience. It can potentially also allow dry season cash cropping, support livestock and fisheries production, and provide supplementary irrigation during the wet season or in times of drought.

Communities located in areas with productive aquifers but situated in more remote areas with no reliable surface water supplies could benefit tremendously if groundwater use could be expanded for dry season and supplemental wet season irrigation as observed from field surveys (Banks *et al. in prep.*) and pilot trials (Clément *et al.* 2018).

There is mounting evidence, which has to a large extent been derived from previous ACIAR research in Laos, to support the view that groundwater has the potential to be utilized more widely for agriculture and help make important inroads towards meeting Lao PDR's commitments to the most pressing Sustainable Development Goals such as 'poverty reduction' (SDG 1) and 'zero hunger' (SDG 2) (Suhardiman *et al.* 2018; Vote *et al.* 2015; Pavelic *et al.* 2014).

The potential for groundwater to assist with these goals is constrained by three overarching factors:

1) *Poor knowledge of aquifer systems* - Despite the understanding of groundwater resources that has emerged on the broad, national scale (Viossanges *et al.* 2018), there remains at the sub-national and local scales a poor understanding of aquifer systems, as reflected by the scarcity of information and data. Planning to enable sustainable use of groundwater for irrigation and domestic supplies is greatly constrained. In some cases, government agencies do not view groundwater development positively due to the implicit investment risks associated with drilling new wells that may be unsuccessful (Coulon *et al.* 2020).

2) *Constraints to farmers in developing the resource* – A host of constraints largely unrelated to water resource availability undermine farmers' participation in irrigation with groundwater – high upfront capital and pumping costs, labour shortfalls, market uncertainty for agricultural products, and more (Clément *et al.* 2018; Suhardiman *et al.* 2018). It is worthwhile to highlight the emergence of solar powered pumping technologies globally, which offers a promising and potentially

powerful means for farmers to pump water at next to no marginal costs as compared to more costly diesel or electricity (Hartung and Pluschke 2018). In the Lao context, there is little or no information available on solar policies or implementation projects at the field level. Examining the prospects for solar-powered groundwater pumping for agriculture could also contribute towards the development of national climate change adaptation and mitigation strategies (NAPA 2009).

3) *Limited capacity for sustainably utilising these resources* – Government agencies, NGOs and the private sector generally lack expertise and fundamental knowledge of groundwater, which negatively impacts on resource development and management. Practitioners lack technical capacity in planning, operation and maintenance activities. Poor quality drilling or pumping practices can lead to drilling failure, aquifer contamination or high running and maintenance costs. Teaching and research capacity are also in clear need to improve as there are few Masters-level and just one or two known PhD-level groundwater specialists teaching in the country. Effort initiated in previous ACIAR research need to be sustained to develop the local capacity.

4 Objectives

The aim of this SRA research was to explore the opportunities for sustainable development of groundwater resources with specific focus on the lowland plains and upland plateau's of Laos. This aim was addressed through the following three objectives:

Objective 1: Establish the potential to develop groundwater for irrigation in key hydrogeological settings in Southern Laos;

Objective 2: Assess the opportunities that solar-powered pumping technologies may provide smallholder farmers seeking to engage in more profitable market-oriented agriculture; and

Objective 3: Enhance the capacity of current and emerging groundwater professionals in Laos.

5 Methodology

5.1 Groundwater potential of major aquifer types (Objective 1)

Previous research has shown that most of the agricultural land of southern and central Laos are underlain by aquifers composed of sandstones and basalts (Viossanges *et al.* 2018). As such, for this research a case study approach was applied to each of these aquifers and on a sufficiently large scale to be more representative of the broader hydrological conditions. District boundaries were selected as a suitable management scale as each of the line agencies have district-level units to facilitate engagement with government and for data access. Selection of a physical boundary (e.g. watershed) was discounted as it could require more complex interactions with multiple districts and provinces.

5.1.1 Case study site selection

The selection of the case study districts was carried out through a two-step process that involved: (i) a preliminary desktop analysis of existing biophysical and socioeconomic data to identify the potential case study districts to be select from; and (ii) field visits and meetings to further evaluate the local context and confirm the case study locations (Figure 1). For the first step, an initial map was prepared together with project partners, the Department for Water Resources (DWR) and the Department of Irrigation (DOI), that prioritized areas according to: (i) aquifer setting (i.e. delineating sandstones and basalts); (ii) proximity to perennial surface water; and (iii) general interest in irrigation development by communities based on key indicators from the national agricultural census of 2010/11 (MAF 2012). This initial map was used to help finalize the selected case study areas by guiding the field visits carried out by the team in December 2019, supplemented by a series of meetings with stakeholders from provincial, district and village levels in Savannakhet and Champasak provinces. Working closely with representatives of the District Office of Natural Resources and Environment (DONRE) and the District Agriculture and Forestry Office (DAFO), the team selected the sandstone aquifer system in Outhoumphone district and the basaltic aquifer system of the Bolaven Plateau in Pakxong district (Figure 2).

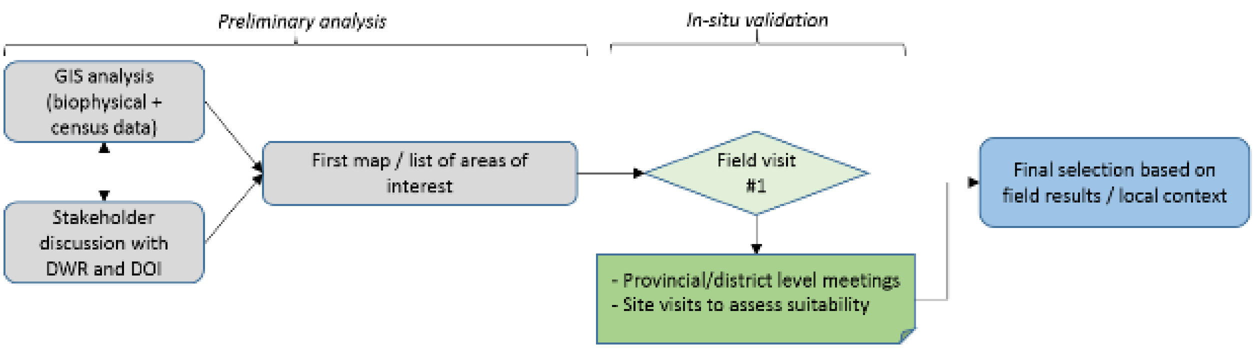

Figure 1. Overview of the processes used for the selection of the two case study districts.

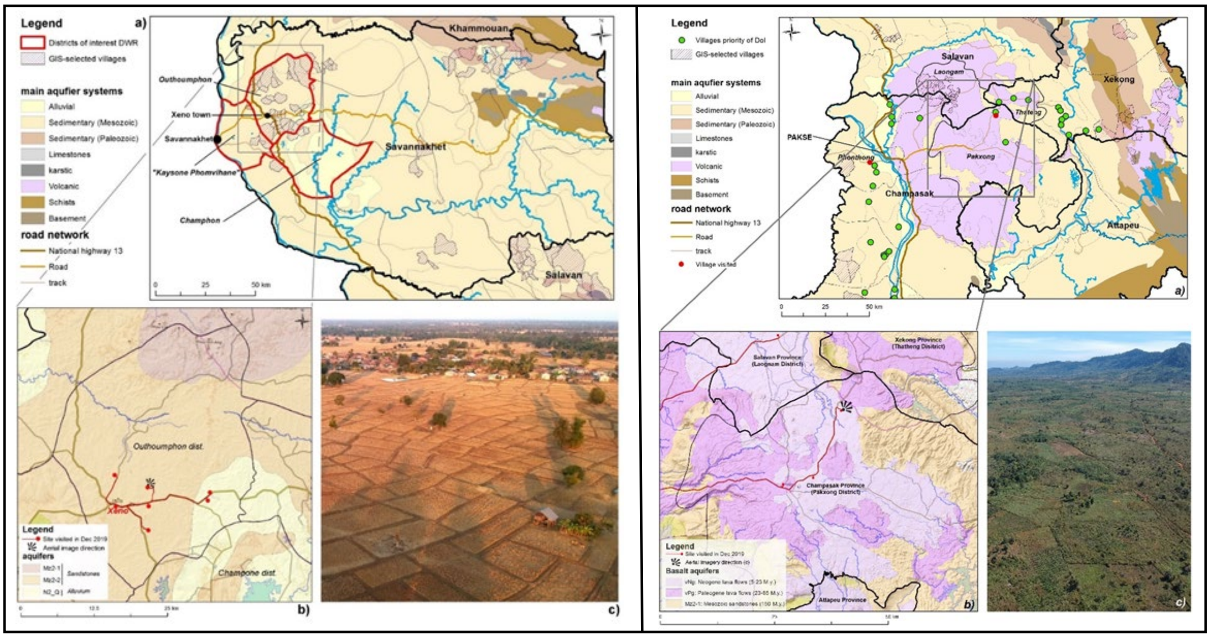

Figure 2. Map of the selected area in the Savannakhet district (left panel) and the Champasak district (right panel) showing: (a) regional map, (b) selected district and (c) typical landscape.

5.1.2 Groundwater monitoring network

Groundwater heads and flow directions have never been mapped across either of the case study areas. Together with district officers from DONRE-Outhoumphone and DAFO-Pakxong, groundwater monitoring networks were established in these study areas. Due to time constraints of the project, existing groundwater infrastructure was selected based on a set of criteria (i.e. type of well, well equipped with pump or no pump, etc). To ensure appropriate coverage of the number of wells and their condition, a grid structure was laid out and wells were pre-selected prior to subsequent field visits. A total of 42 locations were established for the Outhomphone network and 54 wells for the Pakxong network. The first "dry season" monitoring campaign was carried out in early July 2020[1]. The "wet season" campaign was carried out in November and December 2020. The first campaign firmly established the monitoring network and was used as a training for district staff that carried out the second campaign. The timing of the campaigns gave a reasonable indication of the seasonal change in groundwater levels but was slightly more compressed than ideal for establishing the groundwater variation between the two seasons.

For Outhoumphone, an automatic water level recorder was installed at an unused borehole in a private compound following agreement from the owner. Daily rainfall data from Xeno weather station, located 1 km away was obtained from January to December 2020. At Pakxong water level recorders were installed in three wells to assess in high temporal frequency, the changes in water table in response to rainfall events.

5.1.3 Drilling company perspectives

Drilling companies operating in the Outhoumphone and Pakxong areas were interviewed to get their perspectives on: (i) groundwater resources in the area; (ii) usage of groundwater; (iii) drilling challenges and solutions; and (iv) anticipated future trends. Most

[1] whilst the field survey was delayed due to COVID-19, and so too, the start of the monsoon in 2020

of the information shared was based on semi-structured interviews to provide the valuable perspectives of groundwater practitioners in the case study areas.

5.1.4 Irrigated area mapping

Owing to travel restrictions within Laos for part of 2020 due to COVID-19, a GIS and Remote Sensing study was conducted to establish the extent of dry season irrigation across two contrasting lowland districts - Outhoumphone district in Savannakhet province and Phonthong district in Champasak province. Outhoumphone is also a focal site for hydrogeological investigations that are part of Objective 1. Phonthong was selected as the project team had previously met with provincial and district officials and undertaken a field visit when this area was being considered as a candidate case study area. From this visit it was apparent that farmers in the district were becoming reliant on groundwater for irrigation.

The most recently available Google Earth satellite imagery was analysed within ArcGIS to provide an assessment of dry season irrigation. For Outhoumphone the image chosen was from 26 January 2014 and for Phonthong from 15 February 2019. In both cases, in a small part of the area (3% of Outhoumphone and 15% of Phonthong) some of the imagery used was from other years due to inconsistent coverage of Google Earth images. Mapping was carried out systematically using manual methods after partitioning the districts into 5 km × 5 km grid cells. The method enabled each irrigated area to be differentiated according to the water sources: defined here as groundwater, river or pond, based on the observed structures surrounding the plots. Selection of areas as under irrigation depended on strict adherence to a set of validation checks to avoid mapping dry season ‘green vegetated’ areas as irrigated, which may have been due to runoff collection in topographic depressions or selecting non-irrigated perennial crops. Georeferenced photographs from the field were compared with the satellite imagery to discern non-irrigated areas that were vegetated (e.g. eucalyptus or sugar-cane). While ground checks were limited, it is thought that the accuracy of the mapping is reasonably good as first-pass estimates. However, household gardens could not be mapped with this method.

5.2 Solar for agriculture (Objective 2)

5.2.1 Solar review

A policy review was undertaken to establish the Government of Laos’ current policies regarding solar energy in agriculture. It sought to identify emerging trends in solar and how the policy environment in Laos compares to those of other countries in the region. Documented examples of the application of solar technologies to agriculture were included where information could be found. The review was largely a desktop study, supplemented by minimal field work and stakeholder interactions.

5.2.2 NAFRI solar demonstration site

Background and concept

The National Agriculture and Forestry Research Institute (NAFRI) solar water pumping site was established by NAFRI in late 2018 to demonstrate the opportunities for expanding the use of solar-powered groundwater pumping to secure the dry season non-rice crop cultivation for livelihood enhancement and climate change adaptation in Laos. This research provided scope to examine its design, operation and performance whilst recognizing that the system was implemented under conditions somewhat different to those in the field (as noted through a comparison with section 5.2.3).

A solar-powered groundwater pumping system was installed at the NAFRI Agriculture and Forestry ‘Learning Garden’ in Vientiane Capital (15°08’14.97” N, 105°47’13.78” E, elevation 191 m AMSL).

At this site three 100 mm wells were drilled to a depth of approximately 60 meters (Figure 3). The Learning Garden was classified into three main growing areas to demonstrate the successful research results and new innovative technologies that were undertaken by various Research Centers within NAFRI. The solar pumping system was installed at borehole no. 1, located at the northwestern side of the garden for demonstrating new rice varieties, cash crops (e.g. maize, soybean, mung bean), greenhouse vegetables and climate smart water and nutrient management technologies, including a fish pathway demonstration. The soils present are sandy loam texture with clay content of 12 to 22% and low organic matter (<2%). The electrical conductivity of the groundwater was measured to be low (~500 µS/cm). The measured depth to groundwater at borehole no. 1 ranged from 10 to 12 metres between September 2018 and March 2019. Total annual evaporation and rainfall ranged between 1,416 and 2,214, and 1,142 mm and 2,290 mm, respectively according to climate data for the period from 1985 to 2018 from the Vientiane Capital meteorological station (17°58.21', 102°34.23').

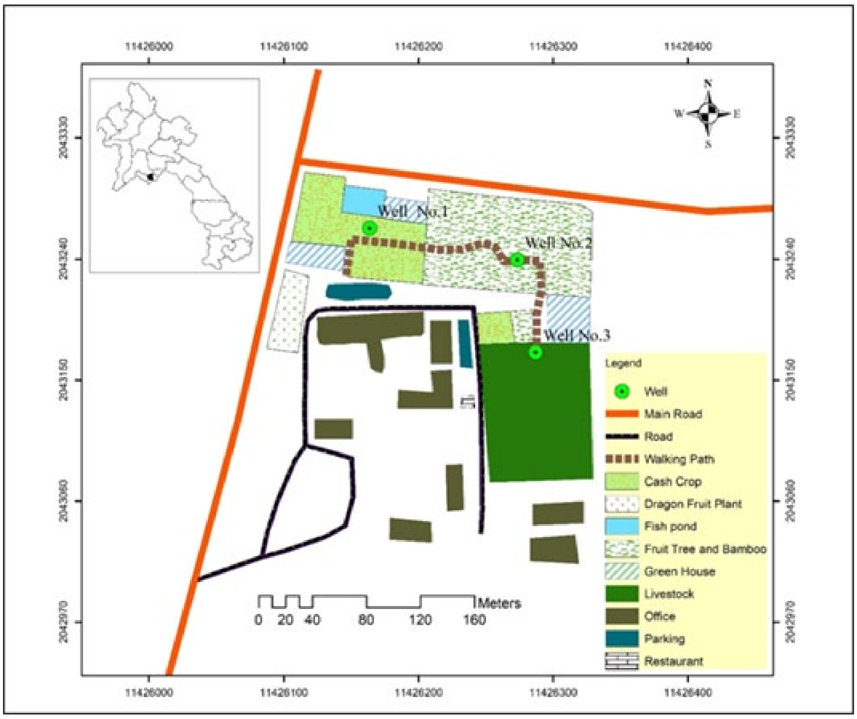

Figure 3. Location of the NAFRI Agriculture and Forestry Learning Garden. The solar-powered demonstration was set up at well number 1.

Design and establishment of the solar system

The solar groundwater pumping system is composed of the solar panels, MPPT solar charge controller, cables, pipes and submersible pump. It operates like any other electric pumping system except that the electrical energy used to drive the pumps is obtained by converting solar energy into direct current (DC) via the solar photovoltaic (PV) panels, and hence varies according to solar energy inputs over the course of each day. In order to meet the power requirements for the submersible pump, 6 solar panels sourced from two manufacturers - Tenxiang (300W, 8.38Ah, 35.8V) and GINTECH (320w, 8.64Ah, 37.0V) - were installed in series, with the capacity to generate up to 1.88 kWh/day. The four GINTECH panels were added when the solar pumping system was upgraded to meet the energy demands of the larger (1.3kW) pump (replacing the initial 0.75kW pump). Solar panels were installed in an open area, facing the sun to the south with a tilt angle of about 20 degrees. A "Maximum Power Point Tracking" (MPPT) solar charge controller was installed to optimize the power production from the PV panels to supply the batteries without overcharging. The system features 8 "Bluesun" brand 75A, 12V batteries connected in series to produce 600A and 96V in total.

A "Feili" 1.3kW DC96V submersible pump that has a maximum discharge rate of 1.1 L/s and capacity to lift water from depths of up to 50 meters. The pump draws on DC power produced by the solar panels. Two concrete storage tanks with a total capacity of around 7 KL were installed in the area connecting with the main pipe running to each planting plot. These tanks are used to accommodate the amount of water pumped to suit the demand, meaning that the system automatically stops pumping when the water level in the tank reaches its maximum capacity. They can also be used to control the irrigation water evenly, including facilitating the supply of nutrients to plants by adding them in the water stored tanks.

5.2.3 Rapid field assessment

A brief field study was designed and carried out in the latter half of 2020 due to the absence of information about the implementation of solar irrigation pumps (SIPs) in the field in Laos. An online search covering company websites, Facebook pages, etc. was first carried out to gain initial information to help identify prospective SIP sites. The search identified 27 solar companies potentially operating in Laos (mainly in Vientiane Capital) that import and distribute various solar products from various countries (primarily China). Each company was directly contacted by phone and the nature of the research explained together with a request to provide solar water pump sales information (this was treated in confidence). Of these, five companies subsequently shared information with the project team, with the remainder unable to share information for various reasons.

Information disclosed by the five companies covered 22 SIP sites in three provinces (Vientiane Capital, Vientiane and Salavanh). From the listing, all of the owners of the solar infrastructure or their representative were contacted by phone to assist in the site selection process. The phone calls were made to establish if the following criteria were met:

- the solar water pump system is used mainly or exclusively for agriculture
- the source of water pumped is groundwater
- access to the site is good (and ideally situated within 100 km of Vientiane Capital)
- agreement by the owner or representative to participate in the study

Six sites spread across six villages were selected for assessment as identified in Figure 4. There were additional sites that were considered were potentially suitable but not visited owing to the short duration of the study. A survey form was prepared in advance that took into account design, costs, performance and perception-related aspects of the study. The criteria used in this study were checked against SIP case study assessments recently undertaken in Kenya (EED Advisory Ltd. 2018) and India (Shirsath *et al.* 2020).

The owner or representative of each SIP site was interviewed on one occasion by project representatives. At the commencement of the site visit all of the interviewees signed a letter of consent agreeing to be interviewed with the stipulated condition that any personal information provided would not be made publicly available without permission. During each visit the solar infrastructure was georeferenced, photographed and, wherever possible, the discharge rate from the well measured using a calibrated vessel and timer. Illustrative photos of the six solar sites are given in Figure 5.

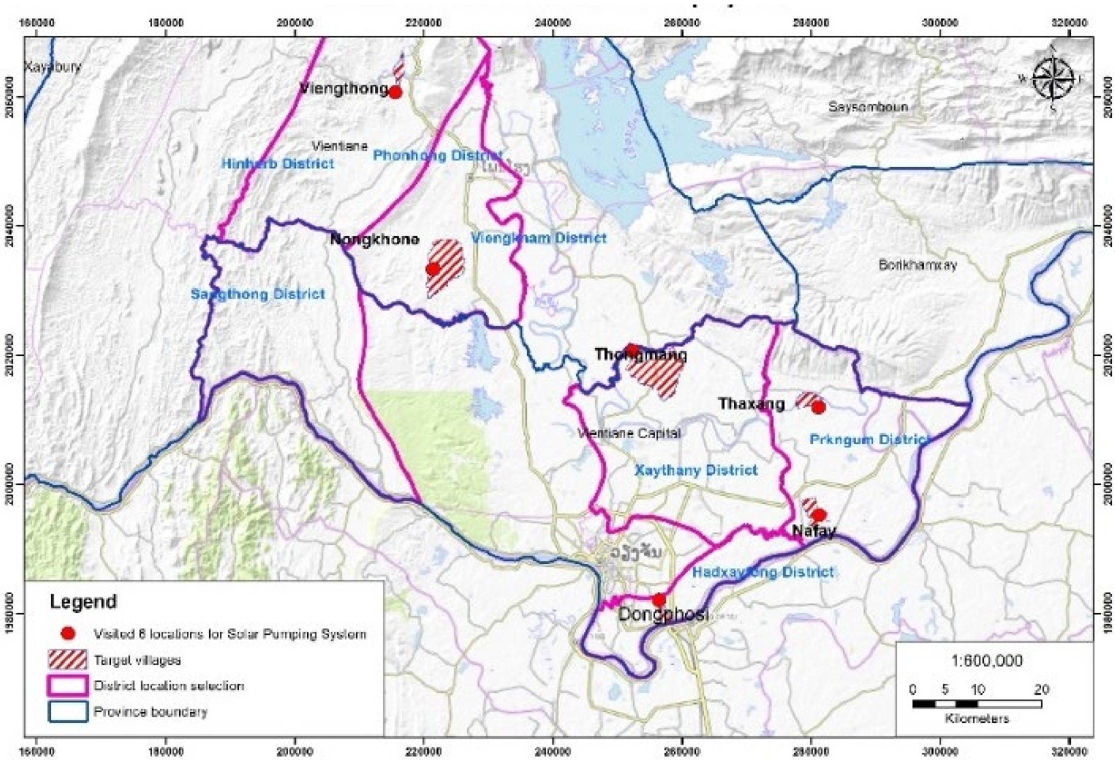

Figure 4. Map showing the location of the six village sites assessed on the Vientiane Plain as indicated by the red dots on the map

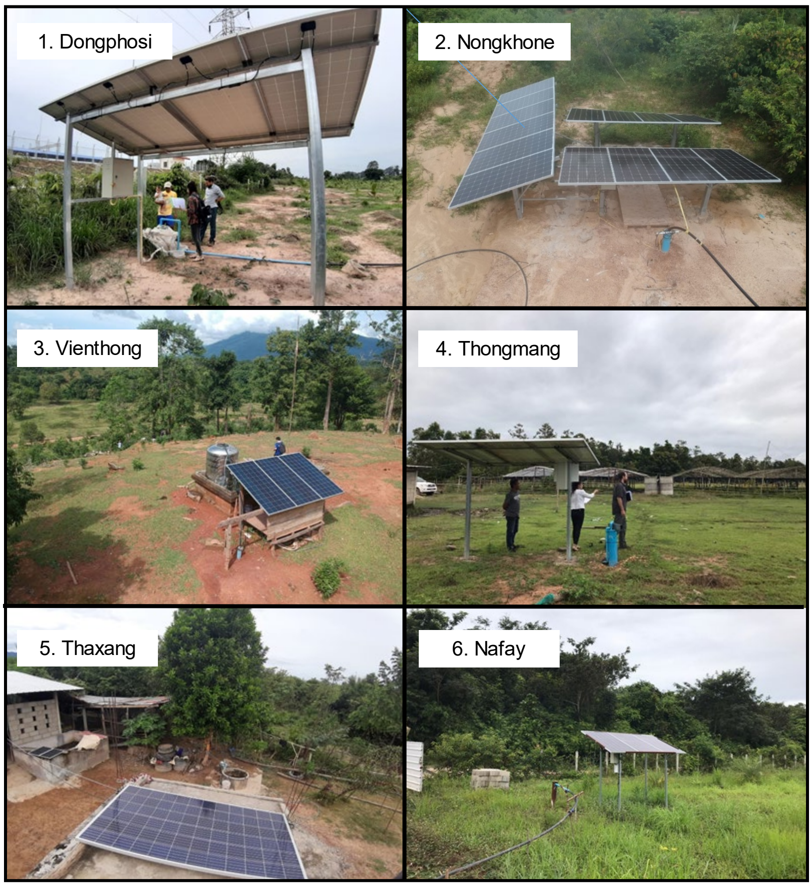

Figure 5. Photographs of the six SIP village sites assessed on the Vientiane Plain

5.3 Capacity enhancement (Objective 3)

5.3.1 Field training in hydro-geophysical techniques

Field investigations conducted on the Bolaven Plateau in Pakxong district for Objective 1 provided the opportunity to share practical field training on a range of hydrogeological and geophysical investigation techniques to Lao groundwater professionals. Pakxong was selected for two reasons: (i) the lack of experience of Lao team members in investigating basaltic aquifers; and (ii) limited data relative to Outhomphone, which was bolstered by a previous and current water supply project (as outlined in section 7.1).

The site was situated 27 km northeast of Pakxong and aligned with a newly constructed production well that was drilled as part of hydrogeological investigations by the DOI.

A comprehensive program of fieldwork and hands-on training was organised that covered the following elements:

- Geophysics – two complementary techniques were used to characterise sub-surface features along transects intersecting existing and newly completed wells
- Drilling – two observation monitoring wells were drilled in the vicinity of the DOI borehole. These were also logged.
- Downhole salinity and video logging – Undertaken at two well locations
- Aquifer pump test - Long term pumping test with water level recorders installed in monitoring wells to characterise the aquifer physical characteristics
- Piezometric mapping campaign – Field survey extending across the Pakxong basaltic plateau

The two near-surface geophysical methods: Self Potential (SP) and Electrical Resistivity (ER) were chosen primarily as they are likely to be to be able to image features/variations in the basaltic subsurface that may be conducive to groundwater flow in this environment. It simplified the logistics of the project that: (i) the National University of Laos, Faculty of Science (NUOL-FS) has an ER system; and (ii) that the SP system is relatively compact, so could be mostly assembled at Flinders University (FU) in Australia, tested and then shipped to our partners in Laos.

A local driller was contracted to drill two monitoring wells. A second drilling company with specialized equipment (SMS Badhan Company) was contracted to conduct aquifer pump tests of the existing DOI bore and the newly drilled monitoring wells as well as to collect some downhole camera imagery.

FU purchased and shipped several field instruments to the in-country researchers in Laos to strengthen the field program. These included: three SP potentiometers (pots), a multi-meter and accessories, as well as a conductivity, temperature and depth (CTD) data logger for well salinity profiling.

The data collection campaign (including training) was conducted over five days in November 2020 and attended by 14 participants from DWR, DOI, NUOL, FU and IWMI (Figure 6). FU and IWMI personnel attended online and acted as “trainers” for much of this work. The timing of this work was severely delayed by travel restrictions earlier in the year due to COVID-19 and a series of severe storms that swept through the area in the latter stages of the monsoon season making it risky to access the field site.

The fieldwork was preceded by a preparatory workshop (run online) organised by FU in June 2020. FU personnel provided descriptions of the two near-surface geophysics techniques that were used as well as the field equipment needed to undertake hydrogeological investigations of the existing and new boreholes at the site. As part of the field logistics and planning, a ‘how to’ video was also created for the SP method, which could be followed by NUOL and IWMI researchers physically participating in the fieldwork.

Several weeks after the fieldwork in December 2020, a half-day workshop was held to discuss the results. Both were attended by all participants. In light of COVID-19, the project team members based in Australia were unable to physically participate in the training and field campaigns and hence on-line methods became the principle mode of interaction.

Prior to the fieldwork, preparations were made to shoot footage for two short videos - one focussing on the potential for sustainable expansion of groundwater use for agriculture on the Bolaven Plateau, and the other specifically on the training aspects. A film crew from Pakse accompanied the team for part of the training.

Figure 6. Hydro-geophysical training in Pakxong district, November 2020

5.3.2 Training to support NUOL-FWR student projects

Project representatives from National University of Laos, Faculty of Water Resources (NUOL-FWR) organized a one day seminar and training workshop on groundwater which was attended by 40 students and 5 FWR staff members. This event covered using a range of practical field techniques for groundwater investigation and analysis (Figure 7). Some of the students applied these techniques in their thesis research.

Figure 7. Undergraduate students at NUOL-FWR learn how to draw groundwater level maps by hand

6 Achievements against activities and outputs/milestones

Objective 1: What is the potential to develop groundwater for irrigation in key hydrogeological settings in Southern Laos?

No.	Activity	Outputs/ Milestones	Completion date	Comments
1.1	Selection of case study areas in Southern Laos	Site selection report for the two districts selected – Outhoumphone in Savannakhet province and Pakxong in Champasak province	February 2020	Completed
1.2	Field data collection and surveys to address data gaps	Groundwater level monitoring networks setup in both districts and two complete rounds of measurements undertaken EC measured at Savannakhet site where salinity is an issue Automatic groundwater level loggers set up in both study areas Interviews with well drillers carried out	November 2020	Ultimately completed but the dry season monitoring was delayed due to COVID-19
1.3	Analysis of primary and secondary data	Hydrogeological prospects report for the two case study areas	December 2020	Complete
1.4	Hydrogeology of the upper Vientiane Plain	Manuscript for peer-reviewed journal building on data sets collected in LWR/2010/081 but not well documented until now	Ongoing	To continue in 2021 with the view to publish in an international journal
1.5	Assessment of irrigated areas	Report quantifying the irrigated area in two drought prone districts with contrasting sandstone characteristics	December 2020	Additional desktop work undertaken due to COVID-19

Objective 2: What opportunities can solar powered pumping provide for smallholder farmers and what are the major constraints?

No.	Activity	Outputs/ milestones	Completion date	Comments
2.1	Policy review on the use of solar energy in agriculture	Report	October 2020	Completed
2.2	Learnings from the NAFRI solar demonstration site	Report	December 2020	Completed
2.3	Rapid assessments of local solar pumping cases	Report and database	December 2020	Completed

Objective 3: What practical measures may be applied to enhance capacity in groundwater in Laos?

No.	Activity	Outputs/ milestones	Completion date	Comments
3.1	Hydro-geophysical training in the Bolaven Plateau	Training report and workshop	November 2020	Training of NUOL staff and students from two faculties in new hydrogeological and geophysical techniques
3.2	Training of district officers in groundwater monitoring	Field training of DAFO/ DONRE personnel	November 2020	Reasonably successful, particularly for DONRE
3.3	NUOL-FWR student projects	Student theses	March 2021	Bachelor and Master student projects are underway. Part of this activity will continue beyond the end of the SRA project.
3.4	PhD research on SW-GW interactions in the Nam Ngum River Basin	PhD thesis and multiple peer-reviewed publications	July 2021	This research will continue beyond the end of the SRA project

7 Key results and discussion

The project findings as presented below in summary form. Project reports listed in section 10.2 provide further information where this section may be lacking.

7.1 Groundwater potential of major aquifer types in Southern Laos

7.1.1 Outhoumphone case study

Biophysical setting

With a population of 90,440 (LSB 2015) and an area of 1,054 km^2, the district of Outhoumphone is strategically located at the junction of two major transportation routes. Its capital, Xeno, serves as a hub that may witness expanded industrial development in future. Agriculture is the main source of income with extensive rice paddy cultivation and sugarcane production in slightly elevated areas. The climate is tropical with an extended dry season. Data obtained from the Department of Meteorology and Hydrology (DMH) indicates Outhoumphone's average rainfall to be 1,218 mm/yr over the 2010-2020 period. In recent years, high and potentially worsening climatic variability has been observed, such as extended dry seasons (e.g. no major rain until mid-July in 2020) and extreme flooding in the adjacent Xe Ban Hieng catchment (e.g. in both 2019 and 2020).

The district lies on the eastern margin of the Khorat Plateau with relatively flat topography which ranges from 151 m to 356 m AMSL. The landscape is drained by several small basins (<500 km^2) in all directions, the most significant being the Xe Ban Hieng River basin forming part of the eastern part of the district. The vast majority of streams only flow seasonally. Field visits in December 2019 and again in July 2020 (i.e. before onset of the delayed monsoon) showed that there is nearly no perennial surface water in the district with most ponds, channels and rivers dry.

Geologically, Outhoumphone district is part of the wider Khorat Plateau system, which experienced extensive marine sedimentation during the Mesozoic (250 to 60 million years ago) depositing up to 600 metre thick sediments in places (Johnson 1983). Large evaporate deposits brought about by shallow lagoon conditions are found in the Savannakhet area (Milne-Home *et al.* 2004). The national 1:1 Million scale geological map shows that the slightly higher elevated hills in the north of the district are formed by of early Cretaceous conglomerate, medium-bedded sandstone, chocolate sandstone and siltstones outcropping along a southwest to northwest eroded range. Further south, the plain is formed by subsequent late Cretaceous fine-grained sandstone, red-brown siltstone and claystone, with evaporate units of halite and gypsum. Some more recent alluvial deposits are found in the northwest of the district along the Xe Ban Fai and Mekong Rivers and southeast in the area of the Xe Champone wetland. Within Outhoumphone, alluvial deposits are mostly absent aside from the southeastern district boundaries.

Resource assessment

Aquifer characteristics

The upper Cretaceous (Mesozoic) sandstones provide the sole aquifer system of the district. Little is known about this specific aquifer system, however, the development of a drinking water supply scheme for Xeno led to the first groundwater investigations being carried out (Knudsen *et al.* 2004; NorConsult 2002). In 2019, a province-wide project to upgrade water supply infrastructure in Savannakhet included a series of pumping tests in the Xeno area as well as other locations (SUNWIP 2019).

Most of the higher yielding and more productive wells that intersect the sandstone are associated with secondary porosity, including joints, fractures, and bedding planes, whilst the primary porosity is expected to be low. The aquifer comprises several inter-bedded layers, and subsequent faulting has induced complex water circulation and spatial heterogeneity. A typical weathering profile is observed near the surface with a top weathered layer underlain by a transition zone and an unweathered layer. NorConsult (2002) reported that the weathering profile increased in thickness away from higher elevations, and can be up to 15 metres before harder, more massive sandstone is encountered.

The district-wide wet season groundwater level elevation, overlain on topography and hydrology layers, shows that a groundwater divide clearly divides the district in two with groundwater flowing generally to the south to southeast and north to northwest directions at an average slope of 0.27% (Figure 8).

Groundwater levels were measured twice for this project (as described in section 5.1.2), once in the wet season and then again in the dry season. The range of groundwater level fluctuations between the two field campaigns averaged 2.3 metres. Logger data shows that groundwater level rises are gradual over the wet season owing to the extensive unsaturated zone (>10 m) at the monitored site.

Existing information on aquifer characteristics from previous investigations (SUNWIP 2019; Knudsen 2004; NorConsult 2002) shows that transmissivity is often low at < 50 m^2/day but can be up to 150 m^2/day where extensive fracturing is observed. In all cases, well yields are mostly below 1 L/s highlighting the limited productivity of individual boreholes.

Recharge

Estimates of recharge near Xeno using multiple methods give a range of values ranging from 3 to 49% of rainfall. Values have a wide range due to high uncertainty in specific yield values of the aquifer used to assess recharge from water level fluctuations.

Groundwater quality

Groundwater quality of Mesozoic sandstones is considered generally of good quality, however, as detailed earlier, salinity is an issue in some areas. District-wide measurement of electrical conductivity (EC) show large variation from 101 to 3,547 μS/cm across 41 sampled locations. Only eight wells have elevated EC (>1,000 μS/cm) and are situated in low lying areas close to seasonal streams. It is possible that closer to stream beds, the upper weathered sandstone has been incised and evaporite layers are either exposed or found at shallower depth below the surface.

Groundwater use

Groundwater is the sole water source in Outhoumphone district. Total water usage for domestic purposes is estimated at approximately 2 Mm^3/yr based on expected demand figures from the Department of Water Supply and population figures taken from the 2015 Census statistics. This equates to an areal average of <2 mm/yr for the district which would likely be a small fraction of the anticipated recharge. Estimates of groundwater irrigation based on irrigated area maps discussed in section 7.1.3 are $<1.3\times10^4$ m^3/yr.

There are no known groundwater dependent ecosystems of significance in the district. The proximity of the RAMSAR listed Xe Champone wetland 10 km to the south/southeast of the district and likely connected to the southern side of the groundwater divide calls for caution in future development. However, given the current very low level of groundwater abstraction, this should not be a subject of major concern in the short to medium term at least.

Drilling company perspectives

Interviews with seven drilling companies in the Outhoumphone area suggests that drillers often have a very good ‘practical’ understanding of the local hydrogeology. Despite this, the success rates in Outhoumphone are often below 75%; somewhat lower than in Pakxong (see section 7.1.2 below). Companies have different pricing strategies to cope with risks –some contractual, others open and subject to negotiation with the client. Borehole costs in the area range from 3 million to 10 million LAK (400 to 1,400 AUD), depending on quality, geological setting, insurance, well-diameter and drilling method used. When asked on scope of groundwater for irrigation in Outhoumphone, most company representatives said that while the number of domestic boreholes are likely to grow with population and economic growth, the irrigation potential is likely to remain low, citing low well yields as the main reason (rather than the investment risks).

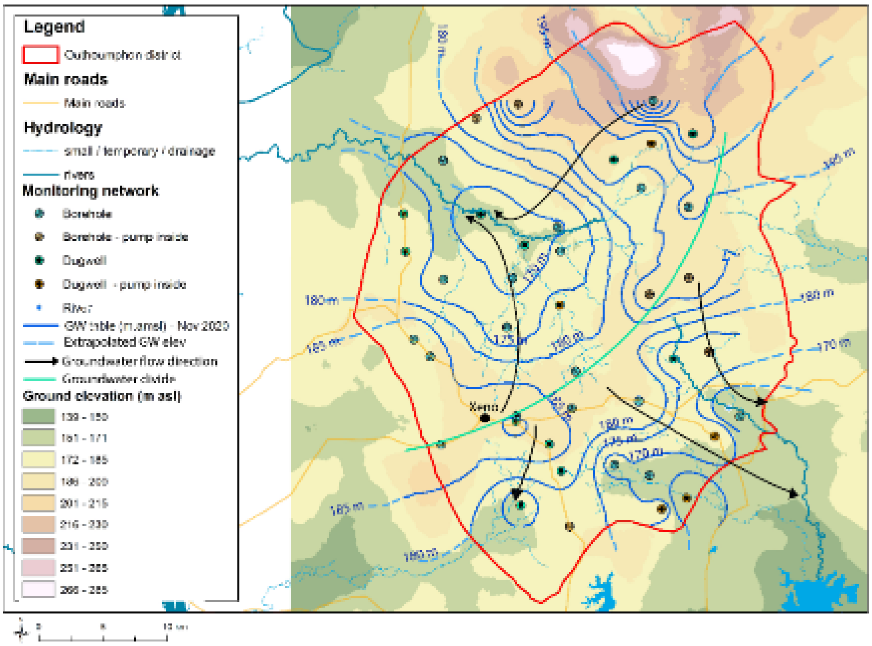

Figure 8. Groundwater level map of Outhoumphone district during the dry season (December 2020)

7.1.2 Pakxong case study

Biophysical characteristics

With a population 83,949 (LSB 2015) and extending over an area of 3,456 km^2, Pakxong district is centrally located within the Bolaven Plateau. Agriculture is the main source of income, and rainfed coffee the main crop. Vegetable cultivation is also common due to the fertile volcanic soils (MAF 2015). Vegetable farmers have received external support to improve farming practices and connect to regional and international markets[2]. Due to coffee cultivation, poverty levels average 16.3%, slightly lower than the national average. However, there is considerable variation, with some villages having levels as high as 78% of the population living below the poverty line. Pakxong district has considerable ethnic diversity – with the ethno-linguistic categories of Lao and Bahnaric Khmer being the main

[2] “Vegetable farmers in the Bolovens are reaching international markets” http://www.fao.org/laos/programmes-and-projects/success-stories/bolovens/en/

groups whilst Katuic, Hmong, TaiThai, Khmuic, Palaungic, Vietic and Tibeto-Burman are present in smaller numbers.

The Bolaven Plateau, rising to an altitude of more than 1,000 metres AMSL, receives significantly more rainfall than the surrounding plains situated at elevations of only around 100 m AMSL, due to orographic effects. Rainfall data from the Pakxong weather station shows average rainfall to be 3,551 mm/yr over the period from 2010 to 2020 and mainly falls between May and October. The highest elevation in the district is 1,600 metres at Phu Phiamay.

The district constitutes the headwaters of several rivers and may be aptly considered the "water-tower" of Southern Laos. No flow data could be obtained by the project team and most of the streams flow ungauged, but field visits during the dry season showed that all major streams continue to flow in the dry season, supported by groundwater discharge (as discussed later). Towards the edges of the plateau most rivers have a significant drop leading to several significant waterfalls.

A lower-altitude secondary plateau located in the southeast of the district has been exploited for hydropower development with two reservoirs built: the 152 MW Houay Ho in the east and the larger 410 MW Xe Pian – Xe Namnoy reservoir in the west. Two additional reservoirs: the 15 MW Xe Namnoy 2-Xe Katam 1 built near the confluence of with Xe Nam Noy, and the 23 MW XeSet 3 on the Set river.

Pakxong district and its surrounding plains feature considerable geological diversity. During the Mesozoic period large deposition sequences led to thick sandstones of the Khorat plateau structure up to several hundred meters thick. Cretaceous sandstones outcrop at the edges of the Plateau as steep forested slope, and as plateau landscape in the southeast of the district. In the east, towards the Annamite range, mostly older Jurassic sandstones are found. Over most of the study area and beyond Pakxong district, sandstones do not outcrop as they are covered by younger Tertiary and Quaternary formations. The Paleogene and early Neogene periods were characterized by intense uplifting and orogeny and intermontane basins were formed and in-filled later during the Quaternary by alluvial deposits. Also during Paleogene and early Neogene, basaltic lava flows formed thick sequences that constitutes the current Bolaven Plateau. The thickness of the basalt flow is generally 100 metres or more at the top of the plateau.

Resource assessment

Aquifer characteristics

As noted above, two major aquifer units are found in Pakxong district: (i) Mesozoic sandstones along the edges of the plateau and in the southeast; and (ii) basalts in the central part of the district. In this study only the basalt aquifer will be evaluated as it is the dominant unit underlying the rich soils of the plateau and has significantly higher potential for irrigation than the sandstones.

Little is known about the aquifer systems of the Bolaven Plateau. A major Japanese International Cooperation Agency (JICA) programme in the 1990s and early 2000s included a comprehensive groundwater assessment of Champasak and Salavan provinces (e.g. JICA 1995). Unfortunately, none of these studies investigated Pakxong district but they do cover the basaltic fans in several districts at lower elevations as well as on the alluvial plains.

JICA (1995) investigations identified the various types of basalt and estimated the transmissivity values to range from <1 to 1,500 m^2/day. Pump testing in Pakxong district during the field training (Batelaan *et al.* 2020), indicated a transmissivity of 500 to 700 m^2/day and a specific capacity of 194 m^3/day/m. This aquifer testing showed that the basalt aquifer holds considerable scope for high discharge.

A groundwater level map prepared for the basaltic aquifer in Pakxong district using the July 2020 data shows a dome-like pattern, with highest levels south of Pakxong town (Figure 9). Gradients are relatively low on the plateau (0.33%) increasing to between 2 and 4% towards the edge of the plateau.

Recharge

JICA (1995) used a water balance approach with limited data on gauged rivers to estimate groundwater recharge for sub-basins of the Xe Don and Champi rivers. Recharge values ranging from 24 to 40% of rainfall was estimated for sub-basins underlain by basalts.

Using automated logger data collected from this study in an abandoned borehole in Pakxong town over the period from July to November 2020 enabled us to make another estimate of recharge. A value of 345 mm, or 11% of 2020 annual rainfall of 2,952 mm was derived; this is somewhat lower than estimates by JICA (1995). Despite the limitations associated with each study, both suggest that recharge on the Bolaven Plateau is high.

Groundwater quality

Very little is known about the groundwater quality in the Bolaven Plateau. Groundwaters of the Bolaven Plateau are generally of very high quality. As salinity is not likely to be an issue, electrical conductivity (EC) measurements were not carried out consistently as part of the study. Instead, random sampling at four locations showed values consistently less than 200 µS/cm. Several companies situated in Pakxong are taking advantage of the aquifer productivity and quality to produce bottled drinking water for both the local market and the national market (e.g. Lava water company).

A regular concern from farmers and one of the reasons evoked for turning to groundwater, is the general view that there is pesticide residues present in the surface water, however, there are no known data to test this claim. Both small and larger commercial scale vegetable production is increasing, and during field visits discarded pesticide containers were evident on farms irrigated with groundwater, with labels indicating they were produced in Thailand and China. Substances identified from the containers included: ZB-Imiprid 70%, Dupont Prevathon, Abamectin and Glyphosate.

Groundwater use

There is an absence of historical groundwater data use in Pakxong district. In this study, the abstraction for domestic purposes is estimated to be around 1.8 Mm^3/yr, which equates to only 0.5 mm/yr across the district. Abstraction is small in comparison to the estimated recharge of 345 mm/yr.

Drilling company perspectives

Drilling companies operating in the Bolaven Plateau are of three sizes according to the equipment available to them. Large companies based in either Vientiane or Pakse own large airlift drilling rigs with Downhole (DH) equipment. At an intermediate level, small DH mounted equipment mounted on small trucks or pick-ups, and mud drilling sleeve (core) also truck mounted (sometimes owned by large companies). The smallest companies based on the Plateau own compact diesel operated rotary, tripod mounted rigs that can be brought to a site using light vehicles.

The drilling companies generally agreed that the groundwater potential of the Bolaven Plateau is high, translating to high success rates. Drilling success rates are typically around 95% (defined as water being found) although this may include a lot of variability in production rates. In the unlikely event that groundwater is not found, usually a second borehole drilled nearby will supply water, indicating a high degree of heterogeneity on a small scale. This differs from Outhoumphone where drillers are not keen to drill again if water is not found unless the client insists and is prepared to carry the financial risk. In the Pakxong area, loss of drilling fluid due to large fractured horizons at depth is problematic for drillers, particularly the smaller operators. In some cases drillers backfill such holes and drill afresh.

All companies agree that the domestic demand will increase in future, simply due to population increase and fears that the surface water might be polluted or that spring water dries out. For irrigation, small companies do not believe the demand will increase, as surface water is present and borehole yield is limited. In contrast, all the larger companies foresee an increase of the groundwater irrigation demand in the Bolaven Plateau.

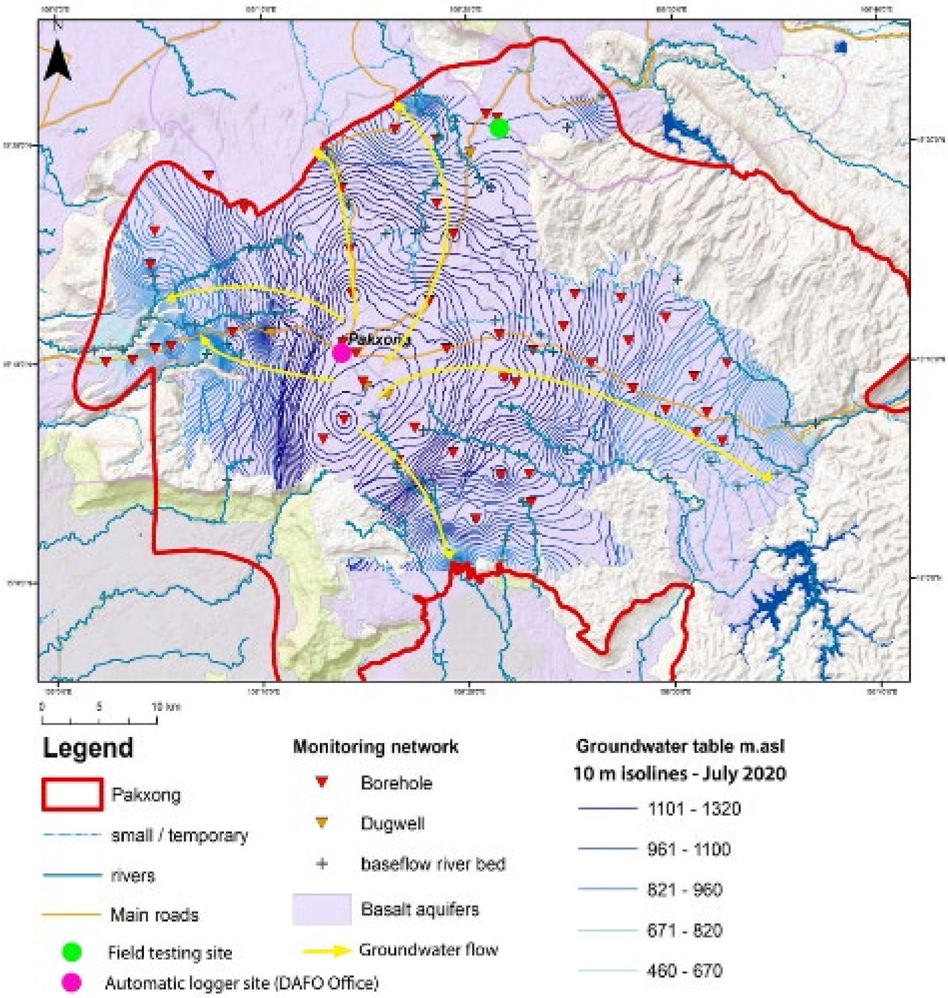

Figure 9. Groundwater level map of Pakxong district during the wet season (July 2020)

7.1.3 Irrigated area mapping

The total dry season irrigation area for Outhoumphone has been assessed to be 24.4 ha (a mere 0.02% of the district area) (Table 1; Figure 10). Groundwater irrigated areas cover just 1.3 ha from 17 identified plots. Irrigation from ponds is the most significant followed by rivers. Villagers prioritize the use of water for domestic household purposes during the dry season months. Only farmers with access to sufficient water from ponds, groundwater or rivers have the opportunity to pursue dry season cropping. Groundwater development in the district is constrained by the challenging hydrogeological conditions - variable well yields and saline water commonly intersected at depth. Villagers tend to produce vegetable crops for household consumption. Villagers also grow watermelon, sugarcane, fruits, vegetables, corn, long bean and cabbage. They sell crops for the market and some sell produce around their village. With greater access to reliable freshwater they would pursue dry season irrigated agriculture for markets.

For Phonthong the total area of dry season irrigation primarily for non-rice crops is 116 ha (around 0.12% of the district area). In this case, groundwater is the major source for irrigation at 41.6 ha, followed by ponds then rivers.

There is a distinct difference in groundwater irrigated areas between the two districts. Whilst both areas are geologically described as Mesozoic sandstones, the sandstones of Phonthong are of older (Triassic-Jurassic age) and potentially more weathered and hence better leached than the Cretaceous age sandstones of Outhoumphone. Whilst it may be an oversimplification to try to relate irrigation development to hydrogeological parameters alone, this may have some bearing.

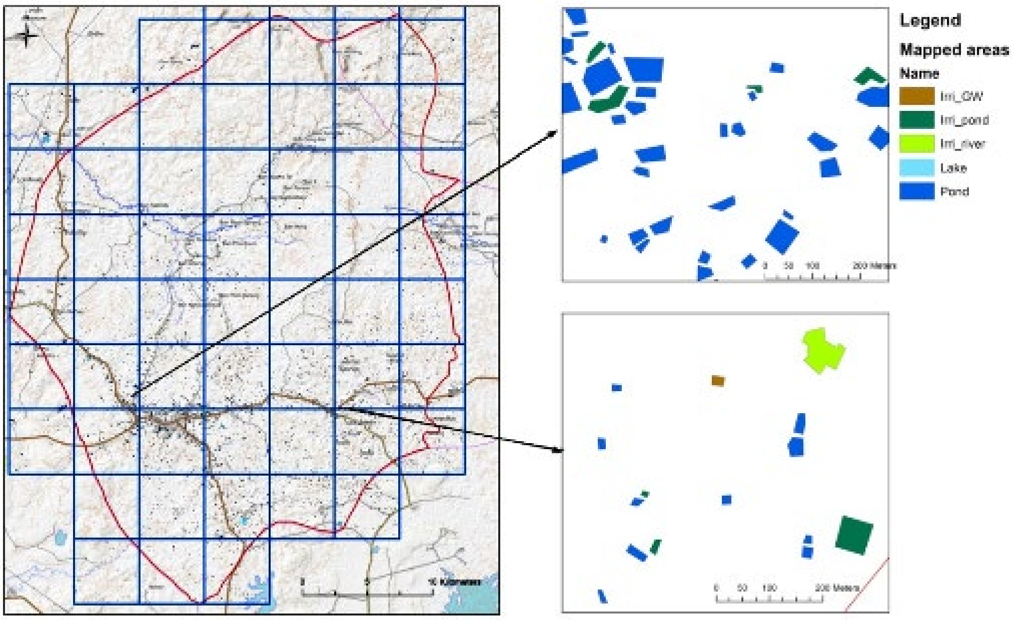

Figure 10. Irrigated areas mapped in Outhoumphone district. Map on the left shows the patchwork of small irrigated plot spread across the district. Maps on the right give examples of two areas at a finer scale.

Table 1 Summary of the irrigated area according to water source in the two districts

	Outhoumphone			Phonthong		
Water Source	Area (ha)	No. plots	Avg. Area (ha)	Area (ha)	No. plots	Avg. Area (ha)
Groundwater	1.25	17	0.07	41.56	524	0.079
Pond	14.65	108	0.135	40.88	370	0.11
River	8.52	19	0.44	32.86	104	0.315
Total	24.42	144	-	115.3[1]	998	-

[1] Only non-rice crops have been mapped. Considerable irrigation of rice adjacent to the Mekong River was not identified

7.2 Opportunities for solar technologies in agriculture

7.2.1 Review of solar policies in agriculture

Background and context

Solar is steadily becoming an important source of energy for Laos to complement the rapidly developing capacity in hydropower (ADB 2019). Laos has large potential for expanding its solar capacity due to its abundant solar resources, much like other countries in the region. Laos receives around 2,000–2,600 hours of sunshine or 200-300 sunlight days per year and annual solar radiation at 1,600-1,700 kWh/m^2 or 3.6–5.5 kWh/m^2 per day (Hubbard 2017).

The Government of Laos seeks to harness its large solar potential to contribute towards sustainable and inclusive growth (MPI 2016). Solar power is particularly important and strategic resource in spurring electrification in areas remote from power grids, including for remote upland communities (ADB 2019). Laos' installed solar PV capacity was 32 MW in 2017 with plans to expand this to 100 MW by 2022 (ADB 2019). By contrast, Laos had 6 operational hydropower plants in 2017 with combined generation capacity of 6,444 MW demonstrating that the generating capacity of hydropower greatly overshadows solar at present and for the foreseeable future at least.

The Ministry of Energy and Mines has outlined policies to promote and develop solar energy within the context of its Renewable Energy Development Strategy 2011-2025 (MEM 2011). In this strategy, the solar energy serves to "*provide energy services to off-grid and remote areas, stimulate private sector investments, and improve energy efficiency in households and commercial buildings*". Links to the agriculture sector are limited to productive uses such as the drying of agriculture products. Government policies in relation to solar have not been regularly updated to account for advancing technological developments and business models.

Solar applications in agriculture

Solar technologies have steadily developed over the past few decades in Laos since its first use in the 1980s to supply electricity for telecommunications systems and vaccine storage in remote areas (Nanthavong 2005). Over this period, solar photovoltaic (PV) technologies, including water pumps, are been increasingly deployed for improved energy access and to offer lower operating costs compared with traditional electric and fuel costs (IRENA 2018). This includes various agricultural applications such as solar-powered water pumping and irrigation. Individual households and agribusinesses have started applying solar power on their farms and businesses, but their applications are not well documented nor being taken into account in government policies. The benefits from solar water pumps for agriculture are primarily associated with reduced operating costs for farmers.

Local communities have begun incorporating solar powered systems in their agriculture activities although their applications are not well documented. For example, Sunlabob, a pioneering solar distributor founded in Laos in 2001, have installed solar PV pumping systems for rural community water supply, with households also utilizing the pumped water for home gardening (Nanthavong 2005).

In Laos, individual households and agribusiness companies have also started to deploy solar technologies in their farms and businesses. For example, a solar-power pump has helped farmers in Khamvongsa village in Phouvong district of Attapeu province in Laos (Thammavongsa 2019). This pilot solar project was planned to be completed in 2020 at a total cost of 900 million LAK (130,000 AUD) to provide 50 KW installed solar capacity to test the pumping of water from a river to rice fields and farms in Khamvongsa village. Another example of solarized pumping applied to public irrigation for growing rice and other crops has emerged at Pak Peung wetland in Bolikhamxay province. The pilot, set up in 2018 by provincial authorities seeks a technological solution to the problem of high electricity costs faced by local farmers (IWMI and World Fish 2019). In a field visit of the Chinese Jackfruit Plantation Company in Phonhong district of Vientiane Plain (site #2 as described in section 7.2.3), the Chinese owner has switched electricity power from grid to solar PV pumping from groundwater to supply water to over 15,000 jackfruit nurseries spread over an area of around 50 hectares. Very preliminary initial results suggest that the electricity fee has been reduced from over 600,00 LAK (86 AUD) to 100,000 LAK (14 AUD) per month with sufficient water supply achieved.

Policy challenges and ways forward

The Government of Laos seeks to promote the use of solar energy in the agriculture sector however, policies from the energy and other ministries seem not well aligned to solar energy promotion. For example, the current Investment Promotion Law (GoL 2016) has yet to clearly offer any investment incentives, value-added tax, and duty incentives and exemptions to both domestic and foreign investors in the solar investment industry in Laos. Investors are often reluctant to invest in the solar industry due to its small market, uncertain profit margins and lack of a regulatory framework (OECD 2017).

To further stimulate solar energy development in Laos, policymakers with support from development actors need to create strong policies to strengthen the enabling environment for solar technologies. Provision of investment incentives and promoting more on public-private partnerships would be positive steps forward.

IWMI and World Fish (2019) have recommended a series of policies and actions are needed to stimulate the solar applications for irrigation:

• Waiving of import duties and taxes on solar power generation equipment;

• Providing concessional credit to farmers for the purchase of solar panels and associated pumping equipment;

• Providing public land for the establishment of banks of solar panels;

• Accelerating depreciation rates on the purchase of solar panels and associated pumping equipment as high as 100% right off in the first year of investment;

• Training PAFO and DAFO staff on technical support to identify system capacities required based on nominated crops and irrigation demands; and

• Expanding the rural electrification fund to support off-grid solar home applications.

Providing incentives of this kind would lower the risks for investment of entering the sector as well as to update and detail guidelines on investing in solar power to facilitate investment both from abroad and from domestic sources. Promotion of solar water pumps would bring associated responsibility to ensure sustainable water resource use through appropriate government policies and awareness raising of water users.

7.2.2 NAFRI solar demonstration site

Water demand and supply

Total water requirements to supply the 0.26 ha of crops irrigated in each plot by the solar pumping system was estimated to be around 25.8 m^3/day based on daily sum of water loss through crop evapotranspiration (ET), soil evaporation (ET), and percolation. The measured abstraction of groundwater in February 2021 was around 17 m^3/day, indicating a shortfall in supply of more than 30%.

Economic cost comparisons

The economical comparisons between solar PV and electrical pumps were analysed using life cycle cost analysis, taking into account the initial cost, operating costs and maintenance costs. Over a 10-year time frame the total costs for electric pumps would be 26.7 million LAK (3.8K AUD), or 14% lower than the solar pumps at 31.1 million LAK (4.4K AUD).

Experience in operating the system suggests that a viable system could be established at lower costs. Reducing the number of panels to 4 would power the pump and increasing the tank size to 14 KL to provide water for 2 to 3 days without the need for batteries would reduce the cost substantially and make solar more economic than electricity over a 10-year timeframe.

Education and outreach

The NAFRI Learning Garden has received a healthy number of visitors including university students, NGO representatives, Government leaders. The site has also been a stopover for important events such as World Food Day, Party Meetings etc. The impressions of the solar groundwater pumping system have been positive and interest from the visitors. The Ministry of Agriculture and Forestry has tasked NAFRI to study the system in detail, including its economics and its working life, which are questions that many sectors are looking for answers to inform the planning of future use of solar energy in agriculture.

7.2.3 Observations of solar irrigation sites on the Vientiane Plain

Solar design and application

All SIPs were are located off-grid and equipped with 0.3-4.6kW solar panels coupled to small (1.1kW or less where known) pumps drawing shallow groundwater from tube wells 18 to 70 metres deep (Table 2). Most sites were used for commercial purposes that included raising various trees, vegetables and herbs. Only two of the sites were established for self-consumption on irrigated areas typically from 1 to 1.5 ha. One site growing jackfruit was being established to irrigate 50 hectares yet there was no evidence that the system could deliver sufficient water for such a large area. Improved irrigation management practices were common, with 5 of the sites having been equipped with drip irrigation systems. All sites were used solely for irrigated agriculture, with no evidence of use for animal husbandry or domestic water supply.

Two thirds of the SIP sites had substituted fuel-powered pump sets, with the remaining one-third of sites involving a new site (Figure 11). All sites were established on financial grounds due to the high cost of pumping from both grid-electricity and fuel powered pumps.

Development timeframes

Despite the limited number of SIP systems assessed and approach to site selection, the available information tends to suggest that solar water development in the areas visited are a fairly recent phenomenon. All sites were established within last two years, and most in the past year (Figure 12). It would appear that the solar pump industry is only just emerging in Laos, although one of the pioneering companies in Laos has installed solar photovoltaic panels for rural community supplies including home gardening since as early as 2005 (Keovilignavong, 2020). Information on the current size of the solar market is unclear. There has been no obvious slowdown in the level of SWP expansion in the months since the commencement of the COVID-19 epidemic.

Financial aspects

In all cases except one the systems were privately financed with one system financed through a government program. The upfront capital costs typically ranged from 8 to 18 million LAK (1.2 to 2.5K AUD), with the exception of the larger site #2 established by a

Chinese investor at a cost of 75 million LAK (10.7K AUD). In two of the six cases, the interviewees who had established the system for commercial agriculture made expressed their expectation of the likely payback time on the initial investment. In these cases the estimated payback time for the upfront investment was stated as two cases as 3 years for the more typical site #3 and 6 years for the largest site #2.

Perceptions

Most of the interviewees were satisfied with the performance of their system, with the description of their system performance given as either medium or high performance.

The need to regularly clean panels and limited pumping capacity in the late afternoon when the sun was positioned low were commonly stated as constraints of the system which would require additional maintenance and changes to pre-existing work schedules.

Sustainability

None of the interviewees expressed any degree of concern surrounding the long term sustainability of the groundwater resources. Almost all sites featured improved agricultural water management interventions in order to ensure that the constrained productivity of the alluvial aquifers underlying the Vientiane Plain (Viossanges *et al.* 2018) were used to their highest productivity.

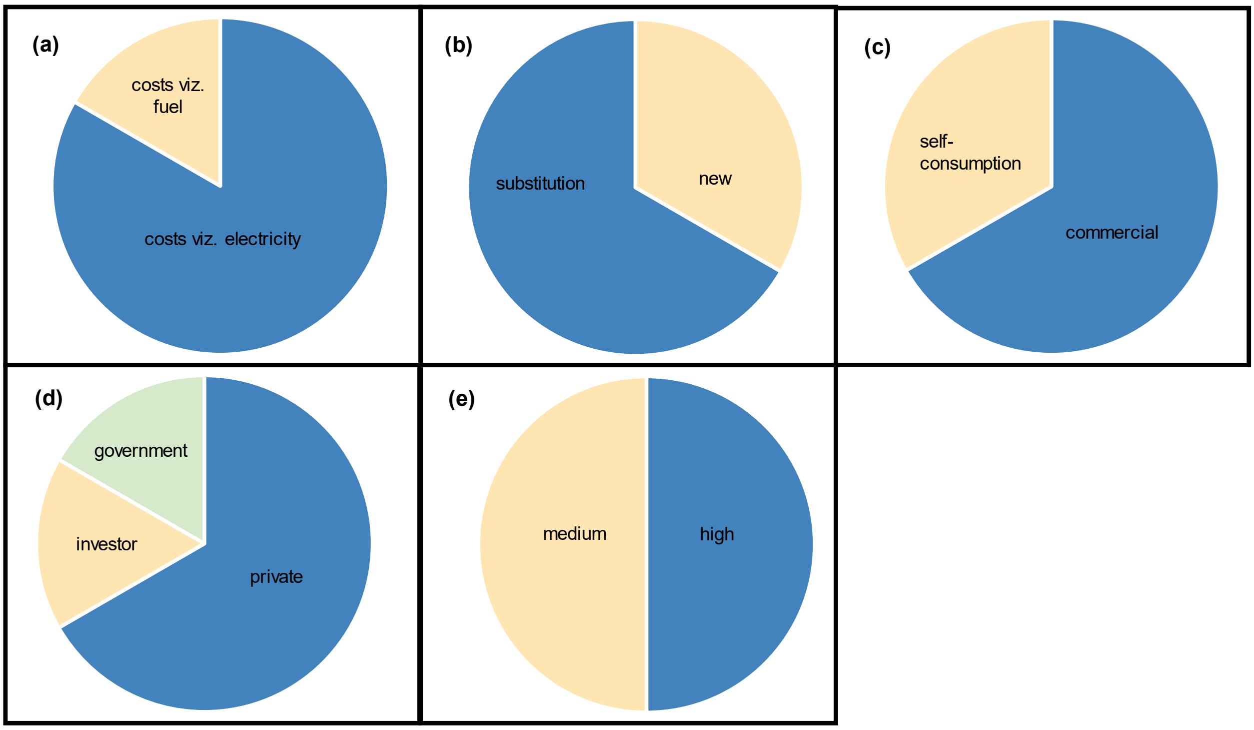

Figure 11. Pie charts showing: (a) reason for investing in SIPs; (b) proportion of new versus substituted infrastructure; (c) purpose for agricultural production; (d) source of financing; and (e) perceived performance.

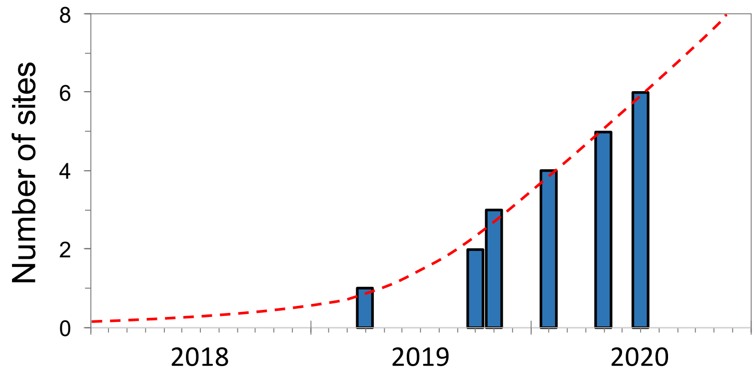

Figure 12. Evolution of solar irrigation pump expansion on the Vientiane Plains. Approximate trend shown by the red dashed line.

Table 2. Summary of the main characteristics of the six SIP systems assessed

No.	TD (m)	PD (m)	SPC (kW)	PS (W)	IFR (L/s)	TC (m^3)	BC (Ah)	Crops	IA (ha)	IM	CC (Kip/AUD)
1	35	5	1.32	1,100	0.69	-	-	coconut, bamboo, wattle, banana	1.1	drip + hose	17.3M/2.5K
2	70	60	4.6	-	1.25	80	-	Jackfruit	50	drip	75M/10.7K
3	52	24	0.99	750	0.47	10	-	orange + cattle/buffalo	1.5	drip	17.5M/2.5K
4	18	13	0.99	-	0.64	4	-	vegetables & herbs (organic)	1	hose	?
5	30	15	0.32	-	0.09[a]	0.7	24	mango, papaya, banana, sugar cane, jujube	1	drip	8.4M/1.2K
6	42	32-36	1.4	-	0.67	6	-	mango, jackfruit, banana, lychee, avocado, coconut	1	drip	10.7M/1.5K

TD = total depth of well; PD = pump depth; SPC = solar panel capacity; PS = pump size; IFR = indicative flow rate as measured from discharge from well during visit; TC = tank capacity; BC = battery capacity; IA = irrigated area; IM = irrigation method; CC = capital cost including installation in Lao Kip and Australian dollar based on exchange rate of 0.000143:1

[a] cloudy weather during site visit

7.3 Activities in capacity enhancement

7.3.1 Field training in hydro-geophysical techniques

The original intent for this part of the study was that a small group of experienced Australian hydrogeologists and geophysicists (the “trainers”) would be able to go to Laos to assist directly with the training and field work. Unfortunately due to COVID-19 this became impossible, and the focus switched to making this a project where the trainers were able to assist with the project remotely, via video where possible, otherwise via email.

A working conceptual hydrological model for the Pakxong field area was established by the trainers working together with attendees in video meetings before the field campaign started. Based on limited geological knowledge, it was assumed that most water flow is likely to move along faults and fractures.

During the field campaign itself, it was important that the trainers were able to stay in contact with the field group; thankfully the mobile phone connectivity in the field area was excellent, and it was possible to hold video meetings between the field group and the remote trainers (Figures 13 and 14).

Two sets of surface geophysical data collected were used to test the model. For each technique a number of potential faults or zones of active fracture flow were identified, based on the interpretation of the data (Figure 15 shows an example where SP and ER data are interpreted together). By considering the data from both techniques jointly, there appeared to be subsurface features e.g. faults or strongly weathered material associated with greater water flow possibly related to active fractures.

Downhole video camera imagery was used to visually see the location of dominant fracture zones and also well construction details. The water quality (measured as electrical conductivity (EC) profiles) of the three wells showed some distinct changes in EC with depth, which appeared to correlate with the change in lithology. In the DOI well there was a sharp increase in EC of about 20 µS/cm at 20 m depth. Overall, the water quality is very good with low salinity (less than 150 µS/cm). The aquifer test also indicated that these fractured rock aquifers are highly transmissive (300 to 900 m^2/day) and likely a sufficient source of water for irrigation.

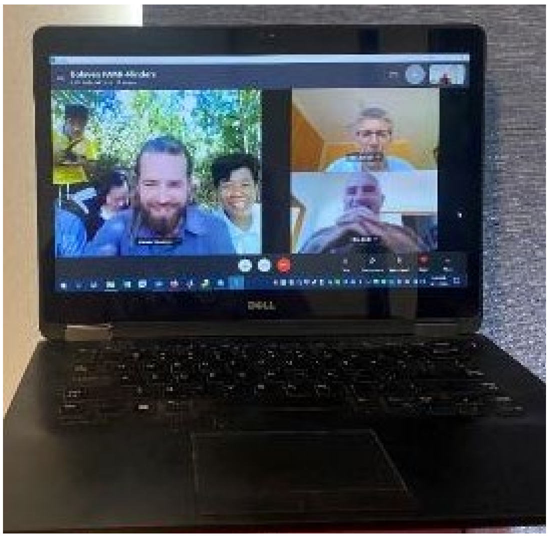

Figure 13. Screen capture of cooperative field work / training session occurring during field training campaign in Pakxong. Mathieu Viossanges and the other attendees are on the left; Okke Batelaan on the upper right, Eddie Banks on the bottom right. Mike Hatch took the picture. As we (in Australia) were not able to travel to Laos for this project as originally planned these video meetings were crucial to the success of the training**.**

Figure 14. Various photographs of group work in the field. From top left to bottom right: Drilling with cores, cores analysis and borehole logging; 24 hour pumping test and overnight recording; group listening to geophysics theory before practice; geophysical techniques applied on site (SP); group discussion and interpretation of results of various methods on-site.

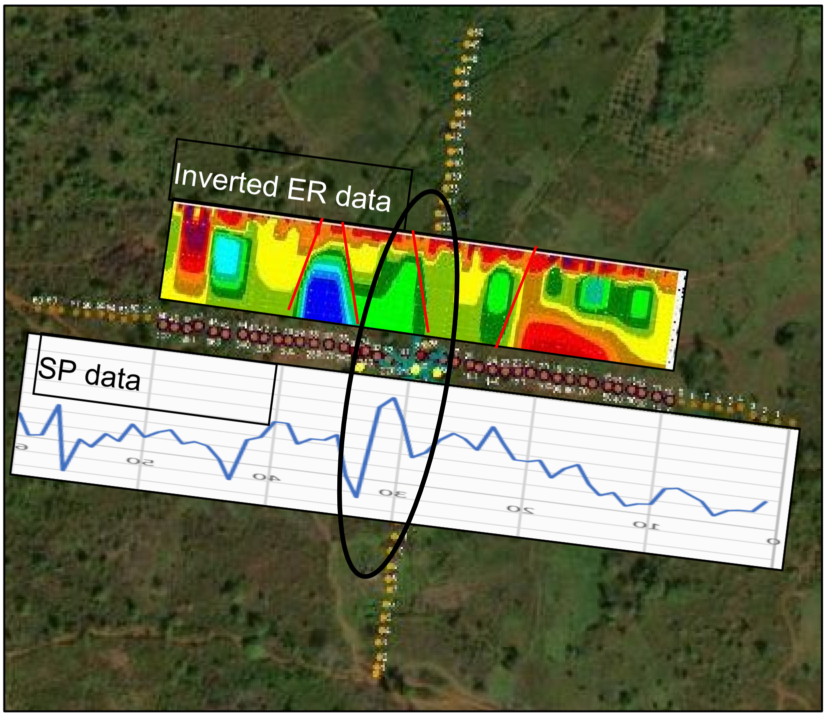

Figure 15. Comparison of SP Line 1 results with inverted ER data (warm colours are associated with conductive zones in the ground while cool colours indicate more resistive zones; interpreted faults are indicated in the ER data with red lines). The interpreted fault in the ER transect at approximately station 200 (black circle) correlates well with a peak in the SP at approximately the same location.

7.3.2 Capacity development at NUOL-FWR

Four groundwater-related student projects were undertaken during the course of the SRA. Two female students jointly completed a Bachelor's thesis on groundwater use in peri-urban Vientiane Capital. Two male students undertook Master level research on groundwater assessments in Vientiane Capital and Champasak, and are due to finish their theses within the final quarter of 2021.

8 Impacts

8.1 Scientific impacts – now and in 5 years

This SRA research has made scientific advancements in two areas:

1. *New datasets collected and analysed leading to improved understanding of the two major aquifer types of Southern Laos.*

   - The data and knowledge from this research will provide the foundations for more substantial investments by the Government of Lao PDR and its development partners in resource assessment and management in the coming years.
   - Monitoring systems established in both case study districts will continue to be used and extended through two development projects[3] thereby adding to efforts to sustainably develop and manage the groundwater resources to improve the socioeconomic conditions of communities in the districts studied and more broadly.
   - Some of the geophysical techniques have been applied in Laos for the first time, and, together with efforts to build capacity within the Lao research community, offer scope for the continuation and advancement of hydro-geophysical studies in future.
   - For Pakxong, this research has revealed a clear potential for expansion of groundwater use for agriculture that may supersede similar conclusions drawn largely on anecdotal evidence.
   - For Outhoumphone, this research has revealed that, despite the urgent need for solutions to address seasonal water scarcity, the aquifer systems are likely insufficiently productive to provide an effective means for smallholders to expand irrigated agriculture. Based on the results of a large town water supply project in the area, there may however be opportunities for larger commercial scale development if planning includes appropriate subsurface investigations.
   - Information on the actual spatial extent of small-scale dry season irrigation practiced using groundwater in two drought-prone districts - Outhoumphone and Ponthong - has been mapped at the plot scale for the first time. Due to the large contrast observed between the districts, the results are likely insufficient to derive estimates over larger areas.

2. *Clarity on the way solar technologies are being embedded in agricultural policies and how they are applied at the field level*

   - The policy setting in relation to solar applications in agriculture are now more clearly understood than prior to this project and some of the ways forward for research to contribute to improved scientific understanding to support policy enhancement and practical implementation have been identified.
   - This research reveals considerable growth in the application of solar water pumps for agriculture in recent years, driven by the reduced costs of solar PV and high

[3] In Sanannakhet this project has contributed to the World Bank Project: Mekong Integrated Water Resources Management (M-IWRM). In Champasak, this project will contribute to a new Australian Water Partnership project that will develop a groundwater management plan for the Sekong Basin in Laos.

costs of diesel. These are bringing direct benefits to smallholders and in some cases, also indirect benefits through foreign investment.

8.2 Capacity impacts – now and in 5 years

This SRA project has mainstreamed and prioritized capacity development into its research activities leading to more substantial positive impacts for individual and institutional capacity. Some of the highlights include:

• Staff and students from two faculties of NUOL have greater skills and knowledge in applying integrated hydrogeological and geophysical techniques. Those involved in the training gained experience in the use of a range of new tools and techniques and skills in how to interpret the data. FU have provided these tools to NUOL to be used for ongoing research and capacity building efforts.

• Four students from the NUOL Faculty of Water Resources have completed or are in the process of completing their Bachelor and Masters theses linked with this project under the guidance of Dr Sinxay Vongphachanh, an ACIAR Alumni who received his PhD at the University of Technology Sydney in 2019.

• Mr Somphasith Douangsavanh is in the final stages of his PhD research on surface water – groundwater interactions in the Lower Nam Ngum River Basin at Flinders University through a John Allwright Scholarship. In coming years, he can be anticipated to continue to make contributions to in-country capacity development as only the second known PhD trained groundwater specialist in Laos.

• Mr Santi Keonouchanh worked as an intern at IWMI for almost the entire the duration of the project and gained considerable experience in groundwater research and management and has the potential to continue to make a contribution as a recent entry groundwater professional in Laos.

• District staff from Outhomphone and Pakxong have been provided training in groundwater monitoring and are equipped to be able to conduct data collection of this kind in the future.

• In the coming years, the case study areas are expected to attract researchers and students looking for new opportunities to utilise the sites and data to conduct new research and teaching.

8.3 Communication and dissemination activities

8.3.1 Communication activities

Information about the project has been prepared for diverse audiences and made available through various channels:

• A website hosted by IWMI: https://sea.iwmi.cgiar.org/show-projects/?C=1045

• A project brochure prepared in English and Lao languages (provided in Appendix 10.1)

• Twitter postings of some of the important project events

- https://twitter.com/OkkeBatelaan/status/1232920502647214080
- https://twitter.com/OkkeBatelaan/status/1329299888237019136
- https://twitter.com/UN_Water/status/1298878418579345408

• A video has been prepared on groundwater-based livelihoods in the Bolaven Plateau and the field training carried out during the project.

- https://www.youtube.com/watch?v=e6KuGBin0aY

The video is being disseminated by the project team through various channels such as Facebook and other social media platforms.

8.3.2 Dissemination activities

During the SRA project, team members were engaged in a host of meetings and consultations to provide and receive information. The stakeholders included:

- government ministries in natural resources, agriculture, public health, public works, energy etc. and in some cases their provincial and district level line agencies
- development organizations planning or undertaking groundwater related activities
- private sector organizations including well drillers and solar companies
- community representatives and groundwater users

• Dr Sinxay Vongphachanh from NUOL-FWR attended the International Research Forum on Science, Technology and Innovation for Sustainable Development held at the National University of Laos on 5 – 6 November 2020. He presented results from SRA research on '*Household Groundwater Use in Tadthong Village, Sikhodtabong District, Vientiane Capital*'. There were about 1,000 people in attendance (including students and staffs from the National University of Laos and other agencies).

• The project team has interacted with representatives from ADB, MRC, World Bank and DFAT in Vientiane responsible for undertaking or supporting projects in groundwater in Laos and the wider region. These interactions have benefited those projects, and provide a pathway of continuation of some of the activities initiated in this SRA research.

8.4 Conclusions

Groundwater use appears to be growing as a result of emerging evidence of the livelihood benefits for smallholder farmers in pursuing intensified agricultural production of non-rice crops, and acceptance of groundwater's unique role in climate change adaptation at the farm scale.

This SRA research has broadly aimed to explore the opportunities for sustainable development of groundwater resources with specific focus on the lowland plains and upland plateau's of Laos. It has done so by addressing three key objectives:

1. Establishing the potential to develop groundwater for irrigation in key hydrogeological settings in Southern Laos;

2. Reviewing policies and practical implementation to gauge the opportunities that solar-powered pumping technologies may provide smallholder farmers seeking to engage in more profitable, market-oriented agriculture; and

3. Undertaking practical measures to enhance the capacity of current and emerging groundwater professionals in Laos.

For the first objective, two areas with promising aquifer development potential have been identified in Southern Laos. They include a drought-prone lowland area underlain by sandstone aquifers in Savannakhet district (Outhomphone district) and a wetter upland basaltic area on the Bolaven Plateau (Pakxong district).

For both districts a preliminary hydrogeological assessment has been undertaken based on the collation and analysis of existing (limited) data supplemented by data from a network of around 40 to 50 monitoring wells and other hydrogeological measurements collected through this study.

For Outhoumphone, where the need for dry season access to reliable groundwater sources is high, the sandstone aquifers present are likely sufficiently replenished but inadequately productive to provide a substantial resource for expanding dry season irrigation. Drillers in the area report frequent well failures as a result of drillhole instability and collapse, low water quality as a result of saline water as common technical challenges. With adequate field investigations these challenges may be overcome and supplies for townships and potentially for larger-scale commercial agriculture may be feasible.

For Pakxong, where the basaltic aquifers are more productive and reliable, evidence collected from this research shows that more entrepreneurial farmers have already started to develop groundwater for high-value commercial crops. There is clear scope to expand irrigation development. Drillers report high success rates for wells, which are supported by the aquifer testing undertaken for this research.

Overall, the approach followed here in applying a case study approach to investigate the major aquifer types of Southern Laos on a sufficiently large (district) scale is considered to have been successful as a result of working closely with government authorities within MONRE and MAF, and despite the short duration of the project.

In the second objective, the opportunities for solar-powered groundwater pumping to provide an alternative to conventional grid electricity or fuel pumps has been explored through policy analysis and the evaluation of a demonstration project as well as actual field operations. Despite the limited maturity of policies on solar technologies in agriculture, the solar industry appears to be expanding rapidly, with over 20 solar companies based in Laos; most of which are also servicing the agricultural sector. A demonstration site operated by NAFRI in Vientiane Capital provides first-hand experience of solar pumping and data is slowly emerging on its functioning and performance. Rapid assessments of six solar pumping sites on the Vientiane Plain show the situation is rapidly evolving (apparently unchecked by COVID-19), which offers farmers and investors with the means to afford the upfront capital cost access to water on demand at effectively little or no marginal cost. Solar water pumping for agriculture remains an emerging technology in Laos and hence, the long term technical performance, economic viability and potential impacts on the groundwater resources remain entirely unanswered at the present time.

The third and final objective involved a cross-cutting effort to enhance capacity for current or emerging groundwater professionals. A one-week hydro-geophysics training course took place in Pakxong in November 2020 that involved 14 attendees from government agencies and NUOL. Training was provided in fieldwork and analysis in new techniques to investigate aquifer characteristics and groundwater quality using geophysical equipment to assist in the siting of new wells, target zones for well completion and aquifer testing and aquifer conceptualisation. In-situ guidance was provided by in-country team members supported by higher level oversight provided remotely by Flinders University due to travel restrictions associated with COVID-19. The project has provided a means for five Bachelor, Master and Doctorate students to undertake thesis research.

8.5 Recommendations

This SRA project has proven successful in terms of scientific and capacity enhancement. Expansion of this research would also hold considerable potential to support improved water resource, agriculture and energy policies.

In keeping with the current country priorities for Lao PDR, ACIAR should continue to prioritize groundwater-related research in Laos through its commitment to enhancing climate resilience and approaches to climate change adaptation for smallholder farmers. Further research would enable a sound basis for establishing the opportunities for sustainable use of groundwater resources in the face of mounting pressures from climate change and emerging developments such as the growth of solar water pumping which has the potential to greatly accelerate groundwater development in Laos, mirroring trends observed in many other countries and regions.

This project points to a number of areas where further research would be warranted. A non-exhaustive list of possible areas of research are proposed for consideration:

1. Comprehensive technical performance and environmental impact assessments (water resource quantity and quality) to establish with rigour the technical performance of solar water pumping at the individual system scale and environmental impacts on broader scales.
2. Understand the operational behaviour and priorities of solar pump users and the factors that affect the extent of daily, seasonal and annual use of SWPs so that strategies to improve water use can be better formulated.
3. Characterizing the reliability of major aquifer types to deliver operational water needs of solar systems for different applications to reduce the financial risks of future implementation.
4. Establishing groundwater monitoring infrastructure (with telemetered data) for major aquifer systems which can also be used as pilot studies to train new Lao professionals in management of groundwater resources as well as locations to conduct training in the use of hydro-geophysical techniques.
5. Assessments of water quality for specific constituents such as agro-chemicals (nitrate, pesticides), salinity, fluoride and microbial pathogens, amongst others, that may present health or environmental hazards and potentially constrain groundwater development.
6. In-depth local groundwater assessments, particularly in areas where existing information suggests a likely high potential for development.
7. Mapping and prioritizing areas with groundwater dependent ecosystems at the national scale and the level of groundwater development that can be sustained whilst maintaining ecological functioning.
8. Tracking the patterns of adoption of farm-scale irrigation with groundwater using remote sensing based methods.
9. Identification of institutional and policy incentives to promote greater groundwater use in the Bolaven Plateau.

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9.2 List of publications produced by project

Peer-Reviewed Publications

Coulon C.A., Pavelic P. and Christen, E. (2020) Drivers for progress in groundwater management in Lao People's Democratic Republic. In: Global Groundwater: Source, Scarcity, Sustainability, Security and Solutions (1st Edition), Mukherjee A., Scanlon B., Aureli A., Langan S., Guo, H., McKenzie A. (Eds.), Amsterdam, Netherlands: Elsevier. pp.451-468.

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Peer-Reviewed Publications Under Preparation

Banks E., Hatch M., Douangsavanh S., Pavelic P., Singsoupho S., Xayavong V., Xayviliya O., Vongphachanh S., Viossanges M. and Batelaan O. (in prep) Cooperation in hydrogeophysics: Enhancing practitioners and institution's groundwater assessment capacity, Vientiane Plain, Lao PDR. *Geophysics Journal* (manuscript submitted).

Pavelic P., Suhardiman D., Keovilignavong O., Clément C., Vinckevleugel J., Bohsung S.M., Xiong K., Valee L., Viossanges M. and Douangsavanh S., Sotoukee T., Villholth K.G., Shivakoti B.R. and Vongsathiane K. (in press.) Assessment of options for small-scale groundwater irrigation in Lao PDR. In: "Groundwater, Resilient Livelihoods and Equitable Growth. Published by IAH-BGID (Burdon Groundwater network for International Development of the International Association of Hydrogeologists).

Douangsavanh S., Batelaan O., Banks E., Viosssanges M. and Pavelic P. (in prep.) Anthropogenic-induced changes in water yield: Trends and driving factors for a Mekong River sub-basin. (manuscript to be submitted to international journal).

Vongphachanh S. *et al.* (in prep.) Household Groundwater Use in Tadthong Village, Sikhodtabong District, Vientiane Capital. (manuscript to be submitted to Lao journal).

Project Reports Completed or Under Preparation

Batelaan O. Banks E. and Hatch M. (2020) Opportunities for sustainable expansion of groundwater use in southern Laos. Draft interim report prepared by FU/NCGRT for ACIAR Project WAC 2018-167, 17p.

Inthavong T., Souliyavongsa K., Phongphachit C., Souvannasing S. and Pavelic P. (2021) NARFI solar groundwater pumping demonstration: A new opportunity to expand groundwater use for livelihood enhancement and climate change adaptation in Lao PDR. Unpublished report prepared by NAFRI for ACIAR Project WAC 2018-167.

Keonouchanh S., Viossanges M. and Pavelic P. (2020) Mapping irrigated area and ponds in Outhoumphone and Phonthong Districts. Unpublished report prepared by IWMI for ACIAR Project WAC 2018-167.

Keovilignavong O. (2020) Review of solar energy development and policy for agriculture in Laos. Unpublished report prepared by IWMI for ACIAR Project WAC 2018-167.

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Hansackda L. and Chitdamlong S. (2020). Household groundwater use in Tardthong Village, Sikhodtabong District, Vientiane Capital. Bachelor Thesis, NUOL Faculty of Water Resources.

Vanmany K. (in prep.) Groundwater for agriculture use in Pakxong District, Champasak Province. Master Thesis, NUOL Faculty of Water Resources.

Vue B (in prep.) Investigation of groundwater status in Xaithany District, Vientiane Capital. Master Thesis, NUOL Faculty of Water Resources.

Outreach Materials

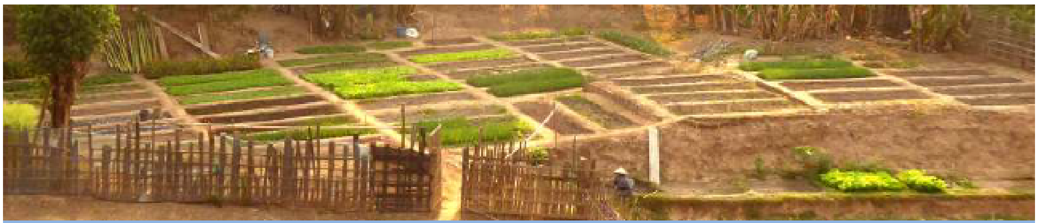
CGIAR Research Program for Water, land and Ecosystems Impact Story: ‘New National Action Plan paves the way for sustainably developing groundwater in Laos’. Available at: https://wle.cgiar.org/new-national-action-plan-paves-way-sustainably-developing-groundwater-laos

Paul Pavelic and Marianne Gadeberg (2020) Developing groundwater from scratch: Lessons from Laos. Mekong Eye, February 2020. Available at: https://www.mekongeye.com/2020/02/06/developing-groundwater-from-scratch-lessons-from-laos/

10 Appendixes

10.1 Appendix 1: Project brochure

A brochure was prepared to provide project information about the project during interactions with stakeholders. Both the English and Lao versions are given below.



Exploring opportunities for sustainable expansion of groundwater use in the lowlands of Laos

Project Area:	Laos (lowland plains)
Timeframe:	July 2019 – December 2020 (Initial Phase)
Financial Support:	Australian Centre for International Agricultural Research (ACIAR)
Partners:	International Water Management Institute, Flinders University / National Centre for Groundwater Research and Training, National University of Laos (Faculty of Water Resources), Lao Department of Water Resources, Lao Department of Irrigation

Background

The lowlands of Laos support around 70% of the population, have by far the greatest potential for expansion of market-oriented agriculture. The lowlands are also prone to drought and regularly face water shortages. Groundwater, which is available year-round offers a potential solution. Communities situated far from reliable surface water supplies could benefit greatly if groundwater use could be sustainably expanded, particularly for irrigation by smallholders.

The national agricultural development strategy [1] recognizes the lowlands as a priority for expansion of livelihood enhancing actions, including diversified cropping. A commitment to enhancing climate resilience in drought-prone areas means that irrigation could evolve as a major user of groundwater. However, information on the aquifer systems is extremely limited, which greatly constrains proper planning and development. Another limitation is the groundwater pumping costs, particularly for diesel pumps. Earlier research [2,3] revealed substantial promise for groundwater to enhance livelihoods in rural Laos however further work is needed to better understand how groundwater irrigation can support agricultural development.

Goal

Explore the opportunities for sustainable expansion of groundwater resources within the lowlands of Southern and Central Laos for livelihood enhancement and climate change adaptation.

Activities

1. Field surveys to select several focal sites in the most promising aquifer typologies in the lowlands;
2. Initial investigations towards establishing groundwater development potential;
3. Review of small-scale solar powered pumped irrigation from groundwater; and
4. Review of groundwater planning and development practices.

Outcomes

1. Improved understanding of the groundwater resource development opportunities in selected areas
2. Assessment of groundwater development and management under different contexts
3. Methods for defining and assessing sustainable development and avoidance of negative environmental impacts
4. Strengthened technical capacity within government, universities and other important stakeholders

Further Information

Dr. Paul Pavelic | Project Leader | International Water Management Institute | E: p.pavelic@cgiar.org | P: +856 21 771 438

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[2] *Completed ACIAR Project LWR/2010/081 https://www.aciar.gov.au/project/LWR-2010-081*
[3] *Society of Exploration Geophysicists SEG supported project: Geophysics to enhance agricultural productivity and livelihoods of smallholder farmers through improved groundwater management of the Vientiane Plain, Lao PDR https://library.seg.org/doi/abs/10.1190/segam2018-2998321.1*

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ໄລຍະເວລາ:	ກໍລະກົດ 2019 – ທັນວາ 2020 (ໄລຍະເລີ່ມຕົ້ນ)
ສະໜັບສະໜູນທາງການເງິນຈາກ:	ສູນຄົ້ນຄວ້າກະສິກຳສາກົນ ແຫ່ງປະເທດອົດສະຕາລີ(ACIAR)
ຄູ່ຮ່ວມງານ:	ສະຖາບັນຄຸ້ມຄອງນ້ຳສາກົນ, ມະຫາວິທະຍາໄລຟລິນເດີ/ ສູນຄົ້ນຄວ້າ ແລະ ເຝິກອົບຮົມນ້ຳບາດານແຫ່ງຊາດ, ມະຫາວິທະຍາໄລແຫ່ງຊາດລາວ (ຄະນະຊັບພະຍາກອນນ້ຳ), ກົມຊັບພະຍາກອນນ້ຳ, ກົມຊົນລະປະທານ

ຄວາມເປັນມາຂອງໂຄງການ

ໃນເຂດທົ່ງພຽງຂອງປະເທດລາວມີປະຊາກອນອາໄສຢູ່ປະມານ 70%, ເຊິ່ງໄດ້ມີທ່າແຮງສູງ ໃນການຂະຫຍາຍຕົວທາງດ້ານກະສິກຳເພື່ອເປັນສິນຄ້າ. ແຕ່ວ່າເຂດທົ່ງພຽງນີ້ກໍຍັງເກີດໄພແຫ້ງແລ້ງ ແລະ ພົບພໍ້ບັນຫາການຂາດແຄນນ້ຳຢູ່ເລື້ອຍໆ. ເຖິງຢ່າງໃດກໍຕາມເມື່ອມາເບິ່ງຊັບພະຍາກອນນ້ຳໃຕ້ດິນທີ່ຍັງອຸດົມສົມບູນ ແລະ ຍັງມີຄວາມສົມປະກັນສາມາດນຳໃຊ້ນ້ຳໃຕ້ດິນໄດ້ຕະຫຼອດປີເຊິ່ງແມ່ນມີຄວາມເປັນໄປໄດ້ໃນການແກ້ໄຂບັນຫາດັ່ງກ່າວ, ໂດຍສະເພາະແມ່ນຊຸມຊົນທີ່ຢູ່ຫ່າງໄກຈາກແມ່ນ້ຳ ກໍ່ສາມາດເຂົ້າເຖິງໃນການນຳໃຊ້ນ້ຳໃຕ້ດິນຢ່າງມີປະໂຫຍດ ຖ້ານ້ຳໃຕ້ດິນໄດ້ຮັບການຂະຫຍາຍແບບຍືນຍົງ, ໂດຍສະເພາະແມ່ນການຜະລິດກະສິກຳຂະໜາດນ້ອຍ ແລະ ພາຍໃນຄົວເຮືອນ.

ອີງຕາມແຜນຍຸດທະສາດການພັດທະນາກະສິກຳແຫ່ງຊາດ [1] ໄດ້ຮັບຮອງເອົາເຂດທົ່ງພຽງເປັນເຂດບູລິມະສິດໃນການສົ່ງເສີມ ແລະ ຂະຫຍາຍການຜະລິດກະສິກຳໃຫ້ຫຼາກຫຼາຍ ແລະ ກາຍເປັນສິນຄ້າ. ແຕ່ວ່າ ການທີ່ຈະຂຸດຄົ້ນນ້ຳໃຕ້ດິນມານຳໃຊ້ນັ້ນກໍຍັງມີຂໍ້ຈຳກັດຫຼາຍດ້ານ ຍ້ອນຂໍ້ມູນກ່ຽວກັບລະບົບຊັ້ນນ້ຳໃຕ້ດິນບໍ່ພຽງພໍ ເຊິ່ງເປັນຂໍ້ຈຳກັດ ແລະ ອຸປະສັກຫຼາຍຢ່າງໃນການວາງແຜນ ແລະ ການພັດທະນານຳໃຊ້ນ້ຳໃຕ້ດິນ. ຂໍ້ຈຳກັດອີກຢ່າງໜຶ່ງກໍ່ຄືລາຄາໃນການສູບນ້ຳບາດານໂດຍສະເພາະແມ່ນຈັກສູບທີ່ໃຊ້ນ້ຳມັນກາຊວນ.ຜົນຂອງການສຶກສາກ່ອນໜ້ານີ້ໄດ້ພົບວ່ານ້ຳໃຕ້ດິນຈະສາມາດສົ່ງເສີມຊີວິດການເປັນຢູ່ຂອງປະຊາຊົນໃນເຂດຊົນນະບົດຂອງປະເທດລາວໃຫ້ດີຂຶ້ນ. ແຕ່ຢ່າງໃດກໍ່ຕາມການສຶກສາໃນຄັ້ງນີ້ແມ່ນຍັງມີຄວາມຈຳເປັນຕ້ອງເຂົ້າໃຈໃຫ້ດີກວ່າເກົ່າວ່າຊົນລະປະທານນ້ຳໃຕ້ດິນຈະສາມາດຊ່ວຍຕອບສະໜອງການພັດທະນາກະສິກຳໄດ້ແນວໃດ [2,3].

ເປົ້າໝາຍ

ສຳຫຼວດໂອກາດໃນການຂະຫຍາຍການນຳໃຊ້ນ້ຳໃຕ້ດິນແບບຍືນຍົງໃນເຂດທົ່ງພຽງທາງພາກໃຕ້ ແລະ ພາກກາງຂອງປະເທດລາວເພື່ອການດຳລົງຊີວິດທີ່ດີຂຶ້ນ ແລະ ການປັບຕົວຕໍ່ການປ່ຽນແປງດິນຟ້າອາກາດ.

ກິດຈະກຳ

1. ລົງສຳຫຼວດພາກສະໜາມໃນເຂດທົ່ງພຽງເພື່ອເລືອກເອົາເຂດສຶກສາຢູ່ຫຼາຍພື້ນທີ່ ແລະ ວິເຄາະໂຄງສ້າງຂອງຊັ້ນຫີນອຸ້ມນ້ຳ.
2. ເລີ່ມການສຳຫຼວດເບື້ອງຕົ້ນ ແລະ ວິໄຈກ່ຽວກັບປະລິມານ,ທ່າແຮງການພັດທະນານ້ຳໃຕ້ດິນ.
3. ສຶກສາການສູບນ້ຳຊົນລະປະທານໃຕ້ດິນຂະໜາດນ້ອຍດ້ວຍພະລັງງານແສງອາທິດ.
4. ສຶກສາການວາງແຜນ ແລະ ແນວທາງການພັດທະນານ້ຳໃຕ້ດິນ.

ຜົນໄດ້ຮັບ

1. ເພີ່ມຄວາມເຂົ້າໃຈໃຫ້ດີຂຶ້ນກ່ຽວກັບການພັດທະນາຊັບພະຍາກອນນ້ຳໃຕ້ດິນໃນເຂດພື້ນທີ່ສຶກສາຂອງໂຄງການ.
2. ປະເມີນການພັດທະນາ ແລະ ການຈັດການນ້ຳໃຕ້ດິນພາຍໃຕ້ສະພາບທີ່ແຕກຕ່າງກັນ.
3. ວິທີການເພື່ອກຳນົດ ແລະ ປະເມີນການພັດທະນາແບບຍືນຍົງ ແລະ ຫຼີກລ່ຽງບັນຫາທີ່ບໍ່ພຶງປະສົງຕໍ່ສິ່ງແວດລ້ອມ.
4. ເພີ່ມທະວີຄວາມສາມາດທາງເຕັກນິກໃຫ້ແກ່ນັກງານວິຊາການຂອງລັດ, ມະຫາວິທະຍາໄລ ແລະ ຄູ່ຮ່ວມງານຫຼັກແຫ່ງອື່ນໆ.

ຂໍ້ມູນເພີ່ມເຕີມ

ດຣ. ໄປນ ພາວາລິກ| ຫົວໜ້າໂຄງການ | ທີ່ຕັ້ງ: ສະຖາບັນຄຸ້ມຄອງນ້ຳສາກົນ | ອີເມວ: p.pavelic@cgiar.org | ໂທລະສັບ/ແຟັກ: +856 21 771 438

[1] ຍຸດທະສາດການພັດທະນາກະສິກຳ ປີ 2016 ຫາ 2025 ແລະ ວິໄສທັດຮອດປີ 2030 ກະຊວງກະສິກຳ ແລະ ປ່າໄມ້, ນະຄອນຫຼວງແຫ່ງ ສປປລາວ.

[2] ບົດໂຄງການ ACIAR LWR/2010/081 https://www.aciar.gov.au/project/LWR-2010-081

[3] ໂຄງການສະໜັບສະໜູນສະມາຄົມນັກສຳຫຼວດທາງທໍລະນີຟີຊິກຂອງ SEG: ສຳຫຼວດທໍລະນີຟີຊິກເພື່ອເພີ່ມຜົນຜະລິດກະສິກຳ ແລະ ຊີວິດການເປັນຢູ່ຂອງຊາວກະສິກອນ ດ້ວຍການປັບປຸງການຈັດການນ້ຳໃນເຂດທົ່ງພຽງວຽງຈັນ, ສປປ ລາວ https://library.seg.org/doi/abs/10.1190/segam2018-2998321.1