Agricultural intensification for food security in rainfed rice-based systems of southern Lao PDR

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Abstract

Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*) investigated pathways towards intensification of rice-based agricultural systems. Deployment of rice varieties well suited to defined environments and to meet known or expected constraints is a viable approach, but requires good knowledge of the yield-limiting and yield-reducing factors in the growing environments. Studies on nutrient – soil moisture regime interactions showed that farmers can manage these factors to enhance productivity. Soil properties can be modified to increase their moisture- and nutrient-holding capacities, which may lead to increased yields. Where water is available, dry-season cultivation of high-value crops extends production and raises household livelihoods. Increasingly scarce and expensive labour is stimulating the shift towards mechanisation and direct seeding to establish the rice crop. The realisation of expectations of high returns and the reduction of perceived risks are necessary for farmers to transition from subsistence to commercial production. This requires consistent policies that mutually reinforce agricultural, rural development and environmental goals. Intensification also requires comprehensive technical and extension support to ensure not only increased production but also increased benefits for farmers now and into the future.

Introduction

Intensification of agricultural production is producing more units of agricultural products per unit of all inputs. It includes novel combinations of these inputs and related innovations. Intensification occurs as a result of three elements: an increase in the gross output in fixed proportions due to the application of proportionately more inputs using existing technology; a shift towards more valuable outputs; and technical progress that raises land productivity. A related term is sustainable intensification, which entails optimising productivity and a range of desired environmental and other outcomes. This paper presents key results and conclusions of the research on crops and soils improvement undertaken as part of Australian Centre for International Agricultural Research (ACIAR) project CSE/2009/004 (*Developing improved farming and marketing systems in rainfed regions of southern Lao PDR*), and provides pointers to the applications and policy implications of these findings for agricultural intensification in Lao PDR.

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Genetic variation and novel genes for intensification

Significant improvement in production and productivity may be gained through the use of appropriate rice cultivars that are resistant to environmental stresses, such as floods and droughts, or are resilient to these stresses. The project assessed the suitability of 13 modern improved Lao rice lines (TDK1, TDK6, TDK8, TDK11, VTE450-2, TSN2, TSN3, TSN7, TSN8, TSN9, PNG1, PNG3, PNG5) evaluated in on-farm trials in Savannakhet and Champassak provinces during the 2011 and 2012 wet seasons (WSs). Rice grain yield was higher in 2012 than in 2011, but there were consistent trends in both years. Rice lines differed significantly in their performance across all sites. Grain yield of TDK1 and TDK11 was stable across the 2 years of the trials. In contrast, TDK8, TSN8, PNG1 and VT450-2 showed plastic yield response, varying between the two growing seasons. Productivity of rice in Savannakhet was stable between the years of the trials; however, grain yield at the Champassak sites varied. Champassak's Soukhouma district produced the highest rice grain yield among the districts in 2012, and contributed significantly to the higher Champassak mean rice yield.

The rainfed environments may not be amenable to production of a single commercial cultivar and may be better served by a basket of lines suited for defined target environments. Further progress in developing high-yielding (beyond 4–6 t/ha), resilient, and pest- and disease-resistant rice cultivars may be realised through access to, and use of, non-Lao genetic resources for breeding of glutinous and non-glutinous rice in Laos. Institutional capacity for enhanced data analysis and interpretation, especially with respect to 'geography by environment' (G × E) to aid interpretation and guide selection and cultivar choice, is greatly needed. Rice growers need incentives (price support, market development initiatives, machinery development and enterprises) to raise crop productivity beyond subsistence levels. Prevailing market prices do not differentiate between 'premium' and 'ordinary' rice.

Intensifying productivity in upland rice-based systems is a major challenge. High-yielding traditional cultivars (Nok, Non, Laboun, Makhinsoung) from northern Laos and an aerobic rice line (B6144F-MR-6) were introduced and evaluated on upland farmers' fields in Xepon and Nong districts in Savannakhet. During the first year of the trials, these entries produced more than twice the grain yield of local check cultivars. However, average grain yields in 2012 were about half those in 2011. The introduced traditional lines from northern Laos consistently produced higher rice grain yield than local check cultivarss in both years. The work described here illustrates that creative, focused and effective use of internal/domestic resources and assets may deliver enhanced crop productivity. This argues for policies that support labour/resources for the characterisation, testing, 'mining' of desirable traits, and dissemination of Laos' heritage varieties. Basic underlying issues—such as the clarification and stabilisation of land-use rights/tenure in the uplands in order to engender responsible use and long-term planning for sustainability of resources and productivity—have to be resolved effectively and ethically.

Enabling farmers to harvest rice even when their rice fields have been inundated can be a means of intensifying production and assuring food security, and a means towards climate-proofing rice production systems. The International Rice Research Institute (IRRI) introgressed the *Sub1* gene, which stops growth for as long as 2 weeks and resumes growth when flood waters ebb, into TDK1 to give rise to TDK1-*Sub1*. TDK1-*Sub1* was field-tested successfully in flood-prone areas of Laos. Flooding occurred in all sites, but flood duration, turbidity and flow characteristics differed among sites. Field data showed that the productivity of the rice line is strongly influenced by the nature of the flood event; whether it took place during the growth of the crop, and the growing conditions after the flood. The variety must be officially released for use by Lao farmers in flood-prone areas. Variety release needs to be accompanied by financial support for dissemination and extension for its use and management by farmers. Issues concerning the uniformity and purity of TDK1-*Sub1* seed need to be assured through a national authority. In order to optimise access and give farmers in flood-prone areas more options, there is a need to prioritise the transfer the *Sub1* gene to other Lao rice varieties. Future breeding and selection activities for durable, flexible rice varieties for the rainfed lowlands may seek to combine submergence and drought tolerance with enhanced nutrient capture and use traits. Provision for labour, facilities and other support requirements are needed to realise these goals.

The rainfed lowlands of Laos and its neighbouring countries are undulating. Improvement of productivity, in the upper toposequence positions of rainfed lowlands, more prone to drought and, therefore, alternating anaerobic and aerobic soil states, was addressed with on-farm testing of three aerobic rice varieties (B6144-MR-6, IR 55423, TDK11), which can be grown in both upland and lowland conditions. These sites comprise the most drought-prone environments in the rainfed lowlands. Rice breeding, selection and testing for drought tolerance, and alternating aerobic and anaerobic conditions in these areas have positive spillover effects on similar efforts in other rice production systems. Recognition of the significance of these rainfed systems from government to its development partners may stimulate support research and development in these ecosystems.

Nutrient × water interactions

With soils of low fertility, low water-holding capacity and variable rainfall, Lao farmers are reluctant to apply fertiliser due to unreliable crop yield responses. We sought to explore opportunities to use combinations of nutrient doses, at rates likely to be economically viable, along with supplementary water application and choice of rice lines to vary the risk of crop loss. Two nutrient treatments (nil; NPK 60:30:30, i.e. nitrogen at 60 kg/ha, phosphorus at 30 kg/ha and potassium at 30 kg/ha), two water treatments (supplementary; nil) and three rice lines were tested on-farm in Savannakhet and Champassak in 2009 and 2010. Locations accounted for 62% and nutrient/water treatments and their interactions accounted for 38% of the variation in grain yield. Rice productivity responded to supplementary water only when nutrients were adequate. At the Savannakhet sites only, there was greater response to NPK and water with line TDK1 when soil fertility was low. These results indicate that farmers have a choice of management options (rice line, water, fertiliser) to raise rice productivity and their livelihoods.

The options that farmers may employ are knowledge intensive, hence there is a need for investments to develop capacity to access, understand and implement these management technologies. The sensitivity of farmers to risks, which impedes intensification, raises the urgent need for the establishment of risk-reduction mechanisms, such as crop insurance.

Fertiliser rates to attain pre-set target yields

Site-specific nutrient management aims to apply the correct amount of nutrients in the soil to achieve uniform crop stands and achieve target crop yields. We estimated the amount of fertiliser (NPK) based on soil properties needed to achieve a national target rice grain yield of 5 t/ha for a range of sites, using a yield prediction model. These rates were field-tested to validate the recommended rates. The fertiliser rate generally recommended nationally for rice (60:30:30) gave the best economic returns. Model-recommended rates achieved target yield in some sites, but these rates were so high that they were uneconomical. Intensifying production through better fertiliser use efficiency has been tested elsewhere and proven successful.

The modelling approach employed in this work may need to be revisited to identify the assumptions and conditions for successful intensification through nutrient management. The key idea from this work and related research on dry season (DS) crop diversification and intensification is that incentives have to be set up for more efficient use of resources and enhanced productivity.

Improving soil characteristics

The logic of this line of research is that improving soil physical and chemical properties will lead to improved nutrient- and water-holding capacity, resulting in improved production. Low levels of bentonite clay were applied to soils in Thasano district of Savannakhet province and in Pakse district of Champassak province. Soil physical properties improved slightly in Pakse compared with Thasano. In contrast, soil chemistry was better at Thasano than at Pakse. Grain yield was consistently higher in plots treated with 1 t/ha of bentonite than the other plots in the 3-year experiment in Thasano. In contrast, bentonite application, at any rate, had little or no effect on rice grain yield in Pakse. These results indicate that the positive effect of bentonite on grain yield at Thasano was due to improved soil water-holding capacity rather than enhanced nutrient supply or holding capacity. Improving soil characteristics through the application of clay such as bentonite, organic matter and recalcitrant carbon (biochar) have been reported to have a positive effect on crop production (Asai et al. 2009; Mekuria et al. 2013). However, the rates of application of soil amendments in these reports were 5–10 times greater than those used in Savannakhet and Champassak.

There is an urgent need to embody management of soil and soil properties in the education and knowledge resources of land/agriculture managers and farmers. This may be implemented through the reform of agricultural extension and education to emphasise the role of land, soil and water resources, and how to manage them efficiently, productively and sustainably.

Post-rice crop production

Rice fields in rainfed lowland areas in the DS are usually fallowed and grazed by livestock because little or no water is available for crop production. On-farm reservoirs capture rainfall during the WS and carry-over to the DS water, which farmers utilise for multiple purposes including DS cash crop production. Some farmers use shallow tube wells meant to supply domestic water needs for DS cropping as well. DS crop systems in southern Laos are akin to multispecies home gardens rather than monoculture stands. Exceptions arise where surface water resources are abundant enough for parcels of land to be in pure maize culture.

In marked contrast to WS rice production, farmers willingly invested in fertilisers for their DS crop production. This may be because crops were targeted for markets, the land area and corresponding amount of fertiliser needed was small, and there were fewer risks involved in the enterprise. Significant amounts of residual fertiliser were found in some farmers' fields, mainly on sandy soils in Champassak, which had positive effects on rice production in the subsequent WS rice crop. Sweetcorn and long beans provided farmers with higher cash income compared with other crops. Crop prices, however, varied and differed significantly among the locations. Savannakhet prices for the DS crops were generally higher than in Champassak.

Stimuli to encourage farmers to engage in DS 'non-rice' production may include information and resources on how to save rainfall and efficiently use it in the DS, and technologies for enhanced use of ground and surface water resources. Programs to enhance marketing of DS produce coincident with campaigns to encourage the consumption of local over imported products would be beneficial to both farmers and consumers. Financial incentives to farmers may involve reduced and/or supported input prices for DS crops. Similarly, availability of better information on supply and demand trends for agricultural produce and inputs in local and distant locations would help in the choice of crops to grow and inputs to apply to crops.

Mechanisation and direct seeding

Labour-saving technologies have the potential to both improve the economic performance of rice production, and at the same time free up labour to be directed towards other activities. Mechanisation in rice production is still in its early stages in Laos, but with increasing scarcity of labour, farmers are beginning to turn to timelier, less labour-intensive and cheaper alternatives to human labour in farm operations.

Labour-saving, as a necessary requirement to intensification of rice production, may involve deploying direct-seeding technologies that may take the form of broadcast or drill seeding. Direct seeding does not require the establishment of a seedbed and the time required to establish a crop is significantly less compared with transplanting. Hence, there is much more flexibility in the timing of crop establishment and 'fitting' the crop into the season. Field data showed that broadcast seeding required similar land preparation to transplanting—ploughing, harrowing and levelling operations, with concomitant labour, time and water costs. In contrast, drill seeding requires less land preparation, and hence less labour, especially if reduced tillage methods are employed. Drill seeding needs a tractor and a drill seeder, which, through proper placement of the fertiliser with the seed, may use less fertiliser without a yield penalty. The drawback of drill seeding is that herbicides—and/or other labour, knowledge, management and resources-intensive technologies—may need to be deployed to control weeds.

There is a need to establish and institutionalise research and development on mechanisation for agricultural intensification in Laos. These will support the growth of local manufacturers and downstream mechanisation-related enterprises, such as spare parts and lubricants dealers and repair facilities. These are needed to ensure the growth and sustainability of mechanisation to support intensification of crop production.

Ecological intensification

Concomitant increasing of production and minimisation of the production system's environmental footprint—through sharply targeted and efficient use of fertilisers and other agricultural chemicals, lower emissions of greenhouse gases and contributing to the maintenance of environmental services and public goods (clean water, carbon sequestration, flood control, groundwater recharge)—are highly desirable outcomes, but are rarely achieved together.

Farmers target rice with the 'perennial' trait for one sowing, which is then left on the field to grow and develop over several seasons. During cycles of growth of perennial rice, grain and/or aboveground biomass may be harvested. These rice lines, by maintaining groundcover on sloping uplands, may minimise soil erosion and produce grain and forage for livestock, with the added convenience of minimised labour for crop establishment. Rice lines from crosses of wild rice (*Oryza longistaminata*) and an established rice cultivar (RD23) were tested in Savannakhet and Champassak. Grain yield among the rice lines differed significantly, but were low compared with inbred rice lines. This line of research is in the early stage of development, but foreshadows a more sustainable way of raising crops in the uplands. It raises the possibility of minimising soil erosion, and regulating run-off water and groundwater recharge, especially in the uplands. The research has a strong gender dimension as it holds the potential for reducing the drudgery of direct seeding rice by 'dibbling', done mostly by women, at the beginning of each WS on upland slopes. For this line of research to flourish, an official recognition of perennial rice as a promising approach for the uplands is needed. Establishment of scientific collaboration with international institutions for advanced research on perenniality in crops in China, Australia and the United States of America would enable Laos to participate and gain access to research programs, facilities, expertise and products.

Use of ecological principles to control pests such as rice gall midge (RGM)—an insect with a larval stage that causes rapid elongation and eventual death of the rice tiller it is infesting, reducing tiller numbers and eventually grain yield—offers opportunities to minimise or completely eliminate the use of insecticides, which may have effects beyond the time and place of application. The project investigated the following three approaches:

- resistance/plasticity centres on the screening of cultivars and lines for resistance to RGM and testing of agronomic practices to stimulate recovery from RGM damage (e.g. fertiliser application after the height of infestation to stimulate tillering)
- pest population control in large areas is the end goal of this work and revolves around testing the effectiveness of synthesised pheromones to attract male RGMs, which may lead to the manufacture of effective baits for trapping male RGMs and thereby skewing the local population structure of the pest
- ecological engineering or modifying the rice environment through the cultivation of profusely flowering crops (e.g. sesame) and/or other flowering plants to attract and favour population growth of predators and parasitoids of RGM, leading to control of RGM populations.

Intensification need not damage the resource base or the environment in which it is embedded; however, there is need for ecological concerns and perspectives to be aired widely, and ecologically based solutions to be adopted and implemented. Policies need not be based on single straightline approaches, employing single 'fragile and unstable' solutions, when multiple approaches may be more stable and more widely adopted.

Research–policy nexus

Intensification connotes increasing levels of production output. Research makes it possible to learn about basic principles underlying systems and to develop technologies that deploy inputs and resources efficiently and effectively to increase productivity. However, gaining knowledge and developing technologies are just part of the intensification equation.

Risk-averse farmers, for example, usually apply little or no fertiliser because drought or flooding may wipe out the crop. Volatile rice prices, unfavourable input/output price ratios, and weak market access also discourage farmers from spending on fertilisers and other agricultural inputs. Water collected and stored in small on-farm reservoirs and water pumped from rivers and/or from the ground make it possible for farmers to apply supplemental irrigation during drought events and engage in post-rice DS vegetable or pulse crops, or forage crop production for livestock. The availability of water during the DS which enables cultivation of high-value crops destined for known, defined markets may move growers to apply fertiliser and other agricultural inputs and invest in more-intensive management practices.

Similar considerations underpin farmers' use and management of other agricultural inputs, including their own labour, and determine the success and sustainability of agricultural intensification. The realisation of expectations for high returns and the reduction of perceived risks are necessary for farmers to transition from subsistence to commercial production. This requires consistent policies that mutually reinforce agricultural, rural development and environmental goals. It also requires comprehensive technical support to ensure that intensification yields not only increase production but also increase benefits for farmers now and into the future.

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