Australian Government

Australian Centre for International Agricultural Research

Final report

Project full title	**Soil-based challenges for cropping in Shan State (nutrient acquisition)**
project ID	SLAM/2018/190
date published	11/05/2023
prepared by	Terry Rose, Southern Cross University
approved by	Dr James Quilty
final report number	FR2023-014
ISBN	978-1-922983-06-0
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The project acknowledges the support of Dr Tin Aye and staff from Department of Agriculture, Land Use Division, Union of Myanmar, particularly Dr Thandar Nye.

2 Executive summary

Agricultural productivity in the Shan state of Myanmar is constrained by many factors, in particular, soil constraints including high phosphorus fixation and generally low soil fertility due to removal of nutrients in residues (especially relevant for potassium). Erosion of topsoil also occurs during the cropping phases of rotations and in the fallow phase used in traditional shifting cultivation. Owing to population pressure, intensification of agriculture has resulted in traditional 6-10-year fallow phases being reduced to 1-2 years, during which time the land does not recover and severe erosion occurs.

The project, led by Southern Cross University in Australia and the Department of Agriculture (DoA; Land Use Division) in Myanmar, aimed to investigate the use of hedge-rows and contour banks to minimise erosion on sloping lands; demonstrate the use of living legume cover crops in maize fields to minimise erosion; investigate the use permanent pastures to replace the traditional fallow phase; and demonstrate the benefits of new soybean varieties and rhizobia for improved soybean production. Field trials were established in the fields of collaborating farmers in the Kalaw Township area in 2020 to investigate the use of hedgerows and living legume groundcovers in maize fields to reduce erosion and increase soil fertility. Owing to Covid-19 and then the military coup in Myanmar, permanent pasture demonstrations and soybean variety trials could not be undertaken in Myanmar. Field trials were instead undertaken near Wollongbar, NSW, Australia (similar high-P-fixing red soils and sloping lands to Kalaw Township area) to investigate whether legumes grown between maize crops (instead of a fallow) would improve maize phosphorus acquisition and growth.

Recommendations for ACIAR – The field trials conducted in this SRA only aimed to assess the potential viability of methods to reduce erosion and improve soil fertility. It was expected that the results of this project would lead to a more thorough investigation of soil constraints and solutions with farmers and other stakeholders in Shan State. Covid and then the military coup put an end to these plans. However, while the field trials in this SRA have limited statistical power, there is sufficient evidence to suggest that hedgerow systems or cover cropping in maize crops could result in improved yield, reduced erosion and can benefit soil fertility. An option to transfer this knowledge to Myanmar would be to bring people from appropriate organisations that are working with farmers and with sufficient agricultural and scientific knowledge out of Myanmar (Shan state) into similar agroecological zones (e.g. northern rivers of NSW or Thailand) and train them in simple hedgerow and cover cropping methods. They could then take this knowledge and capacity back to Myanmar to implement with farmers.

3 Background

A meeting with the DG of DAR and one with Director Land Use Division (LUD), included unprompted articulation that the soil issues of Shan State are their highest priority, even higher than further research into pulse-based systems in the Central Dry Zone of Myanmar. A subsequent scoping study undertaken by a team of researchers from Southern Cross University and La Trobe University in late 2018 confirmed soil issues of the Shan State as a priority for DAR and LUD, as well as for regional officials within Shan State.

Previous ACIAR investment (SMCN/2014/050) in understanding social and environmental issues in the historically and culturally significant Inle Lake region indicated that soil erosion from cultivated lands within the catchment were having a significant impact on the health of the catchment. The study acknowledged that reducing sediment and nutrient loads into the catchment through better soil management was required for longer-term sustainability.

Other ACIAR projects with relevance to the proposed project are SMCN2014/049 – ‘Improving maize-based farming systems on sloping lands in Vietnam and Lao PDR’, and SMCN/2011/047 - ‘Increasing productivity of legume-based farming systems in the Central Dry Zone of Myanmar’.

4 Objectives

The broad aim of this project is to understand key soil constraints in the Kalaw Township area of the Shan State and implement on-farm research trials to address soil fertility decline and soil erosion impacting on regional waterways. If successful, the model trial and demonstration approach used in this project could be implemented across a wider number of Township areas in the Shan State in subsequent projects. The four key objectives are:

Objective 1 – Minimise erosion on sloping land using productive pastures

Rill and/or sheet erosion are observed to some degree on cultivated, sloping lands in the Shan state regardless of the crop being grown or soil type (red or yellow earths). Severe erosion is also observed in fallow land where a 1-2-year fallow phase has replaced the traditional 6-10-year fallow phase due to population pressures. Replacement of a fallow phase with a productive legume-based pasture (including optimising legume species and rhizobia) will be investigated for potential to minimise erosion while maintaining yields and overall profitability of farming on these lands.

Objective 2 – Minimise erosion on sloping land using hedgerows

Research in neighbouring countries has shown that farmers are more willing to adopt simple and cheap means by which to contour sloping lands, such as the use of hedgerows, compared to the more expensive practice of contour banking. The use of several species used as hedgerows will be investigated for potential to minimise erosion on sloping crop lands.

Objective 3 – Minimise erosion in maize crops through use of inter-row cover crops

Maize is a major crop in the Shan state. Yields are typically low (2-3 t/ha) and substantial erosion occurs during the growing season and after harvest due to lack of ground cover. Increasing the row spacing and sowing maize directly into a permanent (legume) groundcover using strip tillage is a promising approach to reducing erosion. The use of permanent groundcovers and strip tillage will be demonstrated using paired paddocks to reduce erosion during the cropping phase.

Objective 4 – Demonstrate benefits of new soybean varieties and appropriate rhizobium inoculants

Replicated small plot trials will be implemented to assess the growth and yield performance of 6 soybean varieties in order to find the best and most economic soybean varieties and effective rhizobium strains to obtain and maintain high soybean grain yield in Kalaw Township.

5 Methodology

***Objective 1* – Minimise erosion on sloping land using productive pastures**

Activity 1.1: Establish three paired sites in the Kalaw Township area comparing traditional fallowing with the introduction of legume-based pastures for livestock production.

Three participatory farmers will be identified and paired paddocks will be established on each farm by splitting a paddock set aside as fallow. Half of the paddock will remain as typical fallow land while the other half will be sown to a mixture of perennial grass and legumes. Fences will be erected about the paddocks to keep livestock enclosed, since at present fences do not exist in the district. Alternatively, animals may be tethered and moved daily. Pasture cages will be used for biomass assessment at monthly intervals, and no animal weight measurements will be taken.

After 12 months the paddocks will re-enter a cropping phase and soil samples will be taken (composite of 10 cores from 0-10cm depth in each paddock) and will be sent to Southern Cross University for analysis. The split paddocks will be sown to maize or rice in the second year and yields and nutrient uptake of the crops will be measured using standard techniques.

Activity 1.2: Within two of the paired sites, establish replicated legume and rhizobia inoculant trials to identity optimum legume species for legume N fixation, groundcover and biomass production on red acid soils of the Shan State. At the same site, optimised rhizobium treatments for soybean crops will also be tested.

Six perennial legume species and soybeans will be assessed in small plots (2 m x 12 m) with 3 replicates per species. Each plot will be split to assess at least two species of rhizobia as well as an uninoculated control. A strip of rice or maize will be grown in each plot as a non-N-fixing reference plant for determination of N fixation by legumes. Samples will be taken from each species every 3 months for assessment of total N and N fixation (using the isotope ratio mass spectrometer at Southern Cross University). Soybeans will be samples at mid pod filling for total N and N fixation. Samples will be dried and weighed in Myanmar and a subsample sent to Southern Cross University for N and N isotope analyses for calculation of N fixation using the ^{15}N natural abundance method.

***Objective 2* – Minimise erosion on sloping land using hedgerows**

Activity 2.1: Establish two trial sites investigating the feasibility of erosion control using hedgerows. Experience has shown that farmers are unwilling to adopt contour banking as an erosion control measure due to the cost and labour involved in establishment, whereas hedgerows have proved a cheap and practical method in neighbouring countries.

Research in neighbouring countries and elsewhere in the world has already demonstrated the benefits of hedgerows for erosion control. The aim of this activity is therefore to maximise extension efforts and understand barriers to adoption.

In year 1, key species will be identified and propagated to ensure sufficient material for plantings in year 2. A project meeting in Shan State at the initiation of the project will *identify sites for propagation of planting material as well as determine numbers of participating farmers and site locations.*

***Objective 3* – Minimise erosion in maize crops through use of inter-row cover crops**

***Activity 3.1*:** Establish three large scale field trials demonstrating three maize rowing systems:

1. *District practice – cultivated land, 2 ft row spacing, 9 inch plant spacing for maize crop. Crop residue removed from field after harvest and burnt*
2. *Living legume cover crop (Pinto peanut; Arachis pintoi) sown at 3 kg seed/ha with maize sown at the same time on 3 ft row spacing with 7 in plant spacing within row, crop residues placed within the maize row after harvest.*
3. *Living legume cover crop (rice bean) sown at 10 kg seed/ha with maize sown two weeks prior to legume sowing on 3 ft row spacing with 7 in plant spacing within row. Crop residues placed within the maize row after harvest.*

Maize biomass and grain yields should be taken from 4 separate lots of 20 maize plants within a row for each treatment.

Five random quadrats (50cm x 50cm) of legume cover crop should also be taken for biomass measurement in each treatment (weight the 5 samples separately). After weighing, a subsample of biomass (about 100g) should be sent to Southern Cross University to measure nitrogen fixation.

Objective 4** – **Demonstrate benefits of new soybean varieties and appropriate rhizobium inoculants

***Activity 4.1*:** *Establish small plot trials that investigate 6 soybean varieties x 3 inoculants (local, imported, nil) x 3 replicates at two sites in Kalaw Township.*

Treatments:

1 Variety-A (Improved variety -1)

2 Variety-B (Improved variety -2)

3 Variety-C (Improved variety -3)

4 Variety-D (Improved variety -4)

Objective 5 – integration of legume cover crops to improve phosphorus nutrition of maize (new objective following military coup and subsequent abandonment of in-country trials)

Activity 5.1: *Establish a replicated plot trial on a high-P-fixing Ferralsol soil to investigate whether replacing a traditional fallow period between maize crops with a legume cover crop can improve maize phosphorus uptake and growth.*

6 Achievements against activities and outputs/milestones

Objective 1: To Minimise erosion on sloping land using productive pastures

no.	activity	outputs/ milestones	completion date	comments
1.1	Establish three paired sites in the Kalaw Township area comparing traditional fallowing with the introduction of legume-based pastures for livestock production.	none	NA	Abandoned due to covid19 pandemic and military coup
1.2	Within two of the paired sites, establish replicated legume and rhizobia inoculant trials to identity optimum legume species for legume N fixation, groundcover and biomass production on red acid soils of the Shan State. At the same site, optimised rhizobium treatments for soybean crops will also be tested.	none	NA	Abandoned due to covid19 pandemic and military coup

PC = partner country, A = Australia

Objective 2: Minimise erosion on sloping land using hedgerows

no.	activity	outputs/ milestones	completion date	comments
2.1	Establish two trial sites investigating the feasibility of erosion control using hedgerows.	Two trials established with erosion quantified	December 2020	

PC = partner country, A = Australia

Objective 3: Minimise erosion in maize crops through use of inter-row cover crops

no.	activity	outputs/ milestones	completion date	comments
3.1	Establish three paired paddock trials investigated strip tillage of maize on wide row spacing using a living mulch Pinto peanut groundcover vs current practice	Two trials established with erosion quantified	December 2020	

PC = partner country, A = Australia

Objective 4: Improve soybean yields through trialling of new varieties and inoculants

no.	activity	outputs/ milestones	completion date	comments
4.1	Establish two replicated small plot trials to test new soybean varieties in the Kalaw Township area			Trials were sown but were not harvested due to the military coup

PC = partner country, A = Australia

Objective 5: (new objective after military coup): Investigate utility of cover crops in the traditional fallow period for improving phosphorus uptake in maize

no.	activity	outputs/ milestones	completion date	comments
5.1	Established a replicated plot trial on a high-P-fixing Ferrosol on sloping land to investigate cover crop impacts on maize P uptake			The trial was conducted at Wollongbar Primary Industries Institute, NSW, Australia on a similar soil type and topography to maize growing regions of the Shan State. This occurred because of lack of access to Myanmar following the military coup.

PC = partner country, A = Australia

7 Key results and discussion

Objective 1 – Pasture phases for improved soil fertility

This work was abandoned due to the military coup.

Objective 2 – Hedgerows for erosion control

Two demonstration trials were established in 2020 on sloping hill country in the Kalaw Township area on farms of U Tin Maung (19% slope) and U Zaw Wan (45% slope) (Figure 1). Five hedgerow treatments were established in each field: no hedgerow, pineapple hedgerow, pigeonpea hedgerow, pigeonpea hedgerow duplicate, grass hedgerow. The treatments were not replicated and data on soil erosion and maize yield was analysed using a 't' test.

To quantify soil erosion losses from each treatment, erosion traps were implemented at the bottom of the slope in each field (Figure 2). At the end of the trial, soil was removed from erosion traps, air-dried, and weighed to quantity erosion losses per field.

Figure 1 – Hedgerows and erosion traps being established in Kalaw Township area by Tin Maung Aye and local farmers

Figure 2 – Erosion traps installed at the base of each field

Table 1. Maize trials with/without hedgerows (2020) **Effect of various hedgerows on dry soil loss due to erosion (t/ha/year)**								
Farmer name	U Tin Maung (Slope 19%)				U Zaw Wan (Slope 45%)			
Dry soil loss	(t/ha/year)				(t/ha/year)			
Replication	I	II	III	Ave	I	II	III	Ave
Maize without hedgerow	3.59	4.48	5.25	4.44b	5.16	4.59	5.45	5.07b
Maize with Grass	1.92	2.35	2.21	2.16a	2.15	2.30	1.72	2.06a
Maize with Pigeonpea 1	2.12	2.58	1.64	2.11a	2.44	2.15	2.58	2.39a
Maize with Pigeonpea 2	2.30	2.87	1.64	2.27a	3.44	3.16	2.87	3.16a
Maize with Pineapple	1.43	2.12	2.75	2.10a	2.30	2.58	2.01	2.30a

Table 2. Maize trials with/without hedgerows (2020) **Effect of various hedgerows on maize grain yield (t/ha)**								
Farmer name	U Tin Maung				U Zaw Wan			
Maize grain yield	t/ha				t/ha			
Replication	I	II	III	Ave	I	II	III	Ave
Maize without hedgerow	6.09	8.30	5.81	6.73a	5.81	4.98	6.64	5.81a
Maize with Grass	7.75	7.47	8.85	8.02c	6.64	7.47	6.36	6.82b
Maize with Pigeonpea 1	7.75	8.58	6.09	7.47b	6.36	6.36	8.02	6.92b
Maize with Pigeonpea 2	6.36	8.30	6.64	7.10ab	5.26	6.36	6.09	5.90a
Maize with Pineapple	7.75	8.02	6.36	7.38b	5.26	5.53	6.64	5.81a

Despite limited replication, the results indicated that hedgerows significantly reduced soil erosion at both trial sites. Further, maize yield was either unaffected or improved when hedgerows were used in fields.

Objective 3 – Cover crops for soil fertility and erosion control

Two demonstration trials were established in the 2020 cropping season on sloping hill country in the Kalaw Township area in farmers' fields.

Figure 3 – Pinto peanut legumes for inter-row cover crops being established as nursery stock in early 2020

Figure 4 – Pinto peanut inter-row cover crops being sown with maize in May 2020 in Kalaw Township

Figure 5 – Pinto peanut and maize in July 2020

Table 3. Maize trials with/without cover crops (no replication)

Effect of various cover crops on dry soil loss due to erosion (t/ha/year) and on maize yield (t/ha)

Farmer name	U Tin Maung				U Zaw Wan			
	Dry soil loss	Maize DM yield	Maize grain yield	Legume biomass yield	Dry soil loss	Maize biomass yield	Maize grain yield	Legume biomass yield
	t/ha/year	t/ha	t/ha	t/ha	t/ha/year	t/ha	t/ha	t/ha
Maize without cover crops	4.16c	14.11a	4.98a		5.59b	12.73a	4.43a	
Maize with Sunn hemp	3.16b	14.66ab	5.26a	12.00	3.87a	13.28a	4.70ab	8.00
Maize with Pinto peanut	2.07a	15.22b	6.36b	12.00	2.73a	13.83b	5.26bc	10.00
Maize with Rice bean	2.55ab	15.49bc	6.09b	18.00	3.21a	14.11b	5.81c	16.00
Stdv	0.90	0.61	0.66	3.46	1.25	0.61	0.61	4.16

The use of living cover crops significantly reduced soil erosion at both sites (Table 3). Cover crops had either no effect on maize grain yield or led to a significant increase in grain yield (Table 3). It is also likely that the legumes would have contributed to increases in soil nitrogen fertility. However, no measurements were taken and trials were abandoned due to the military coup before any longer-term effects of cover crops would be assessed.

Objective 4 – New soybean varieties for the Kalaw Township area

Two replicated small plot trials were established in local fields on 21 July 2020 and 22 July 2020 in the Kalaw Township area (Figure 6).

Figure 6 – Emergence of soybeans in replicated small plot trial in farmer's field

Trials were not harvested due to the military coup.

Objective 5 – integration of legume cover crops to improve phosphorus nutrition of maize

Evidence from field trials suggests that growing legume crops before maize crops can improve the phosphorus uptake and growth of maize (e.g., Jemo et al. 2006). This phenomenon may assist in improving phosphorus use efficiency in Shan State of Myanmar on P-fixing soils used for maize cultivation. However, maize phosphorus uptake following soybean crops was not improved compared to maize following maize (Vandamme et al. 2012), suggesting that legumes do not always improve phosphorus nutrition of subsequently grown cereal crops, and it is possible that the legume species is important. The proposed mechanism behind the improved phosphorus use efficiency is that legumes solubilise non-labile phosphorus pools in the soil through a combination of rhizosphere acidification and carboxylate release, and some of this phosphorus remains available to subsequent crops.

On a high-P-fixing Ferrosol, we recently found that P uptake of maize following cereals or faba bean was superior to that of maize following a fallow, despite the fact that more P was removed from the soil (and exported from the field) where faba bean and wheat were grown compared to the fallow (T. Rose, unpublished data). Preliminary evidence suggested that the improved maize uptake after wheat or faba bean may have been due to greater presence of AM fungi in these treatments compared to the fallow. In Shan State of Myanmar, where maize is typically grown in the wet season following a fallow in the dry season, it is possible that a decline in AM fungi inoculum over the fallow period may be impacting on maize P acquisition.

The aim of the trial conducted under Objective 5, at Wollongbar Primary Industries Institute, NSW, Australia, rather than in Myanmar due to the military coup, was to assess whether the type of legume grown (e.g., faba bean which hosts AM fungi vs narrow leaf lupin which is a non-host for AM fungi) affects P uptake of subsequently grown maize, and whether the use of AM fungal inoculants can improve P uptake.

Methods

The field at NSW DPI Wollongar, NSW, Australia, was sprayed with glyphosate in June 2021. The soil type was classified as a Rhodic Ferralsol (FAO-UNESCO, 1974) and an experiment with four winter treatments (faba bean, wheat, narrow leaf lupin and fallow) and 4 replicate plots of each treatment was laid out in a latin square design.

On 25th July 2021 faba bean, wheat and narrow leaf lupin fallow were sown. Wheat was sown with a Duncan Renovator Seed Drill with 150 mm row spacing. Faba bean and lupins were sown with a Norseman Techni-plant Precision Planter at 450 mm row spacing. Faba bean and lupin seeds were inoculated with appropriate rhizobia prior to sowing. Urea was applied to wheat plots at a rate of 150 kg N ha^{-1}.

Figure 7 – Winter crops prior to termination at Wollongbar Primary Industries Institute

Biomass assessments were made on the wheat, faba bean and lupin crops on 6th October 2021 before biomass was removed with a forage harvester and taken off the plots (Fig. 7). The site was then sprayed with glyphosate to maintain a weed-free seedbed prior to maize sowing.

Maize (cv. Pac607IT) was sown on 24th November 2021 was sown at 25 kg seed ha^{-1} with 800 mm row spacing. Each plot was split so that 4 rows of maize were sown with uninoculated seed, and four rows were sown with seeds inoculated with a commercial AM fungal inoculant.

Maize seedling biomass was assessed on 12 January 2022 by randomly removing 5 plants from each of the outer rows in each plot. Roots were washed free of soil using tap water and shoots were cut free of roots and dried in an oven at 60 ºC for 5 d. Roots were stored in ethanol for subsequent assessment of AM fungal colonisation. However, in light of no impact of AM fungal inoculants on seedling biomass, root AM fungal assessments were not undertaken.

Maize biomass at maturity was assessed on 21 March 2022 by severing all plants in the middle two rows at ground level and drying shoot material in an oven at 60 ºC for 7 d.

Results and Discussion

There was a significant effect of winter fallow treatment on maize seedling biomass at 7 weeks after sowing, with significantly higher biomass following a winter fallow or faba bean crop than following winter wheat (Fig. 8). However, there was no significant effect of inoculant treatment. At maturity, there was no significant effect of winter fallow treatment or inoculant treatment on maize biomass. In the absence of any significant effect of AM fungal inoculants on seedling biomass production, root AM fungal colonisation was not assessed on root samples. The reason for a lack of effect of AM fungal inoculants on maize seedling growth in a P-deficient field is not known. It is possible that the AM fungal species in the commercial product are generic species, and these species are not necessarily those species that are beneficial for maize. Regardless, crop rotation had a significant effect on maize seedling growth, with maize biomass following faba bean and lupin crops not significantly reduced compared to the fallow, despite substantial amounts of P being removed from the field in legume biomass. This would suggest that growing legumes in the fallow period in Myanmar may improve soil nitrogen fertility without having any negative consequences for P fertility.

Figure 8 – Effect of winter fallow treatment on maize seedling biomass

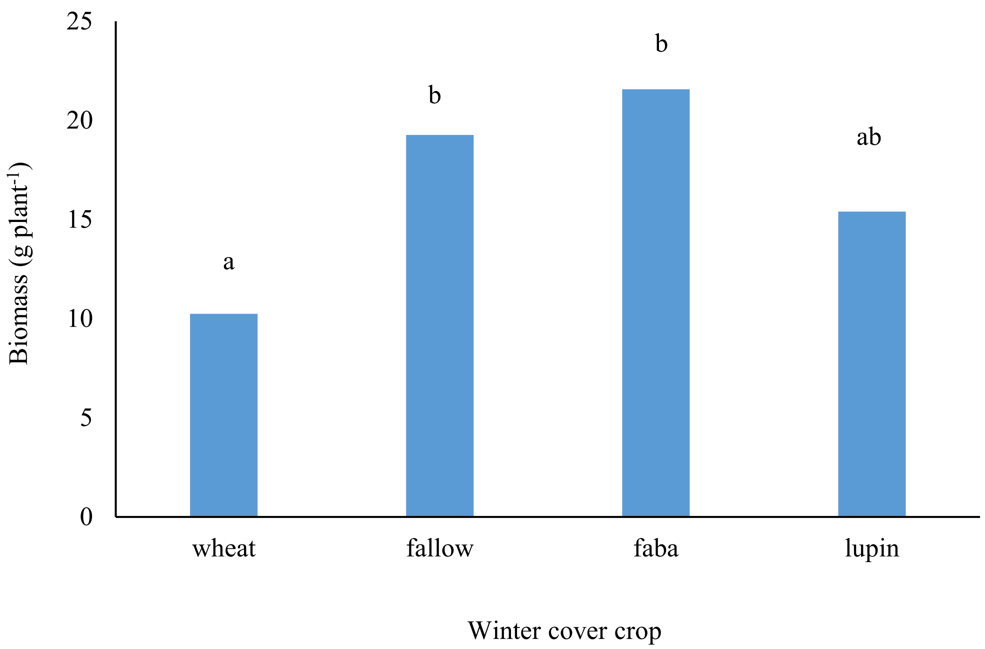
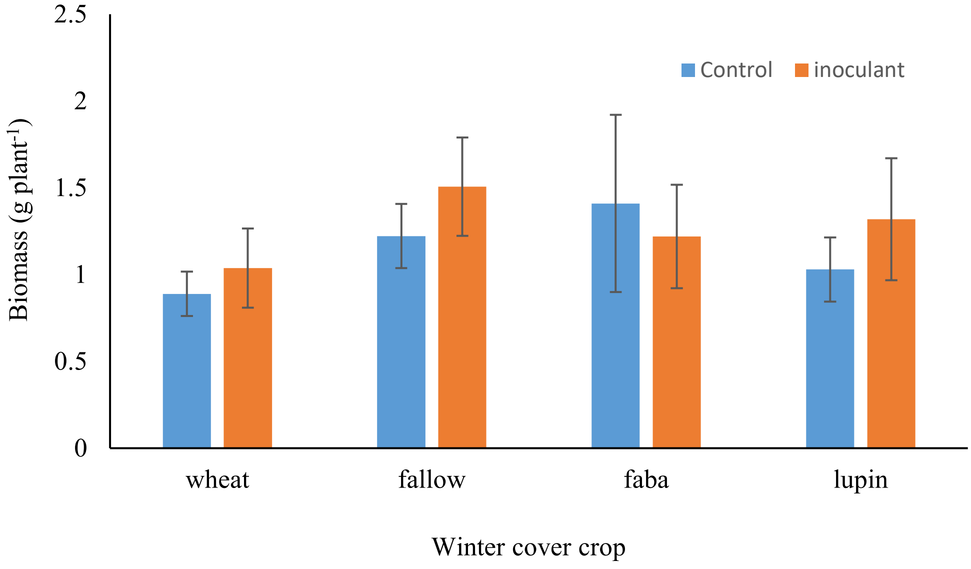


Figure 9 – Effect of winter fallow treatment on maize biomass at maturity



8 Impacts

8.1 Scientific impacts – now and in 5 years

Owing to the abandonment of trials after the military coup, insufficient trial data was collected from Myanmar field sites to form valid conclusions. However, preliminary data suggested that the use of either hedgerows or living cover crops reduced soil erosion and had no negative impact on maize grain yields.

The trial conducted in Australia (NSW DPI Wollongbar) resulted in novel findings suggesting that the inclusion of legumes in place of a fallow could improve soil nitrogen fertility without impacting negatively on maize P nutrition. There was no significant effect of the commercial AM fungal inoculant on maize growth in a P-deficient field, which raises questions as to whether commercial AM fungal strains need to be optimised for specific crop species. However, all findings from the field trial (one site, one season) would need to be confirmed in subsequent trials before valid conclusions could be reached.

8.2 Capacity impacts – now and in 5 years

Two Agricultural Graduates from DoA attended planning meetings and field site establishment and were trained in establishment of contour banks and hedgerows by project staff member Tin Maung Aye in May 2020. No further capacity building was possible due to the military coup.

8.3 Community impacts – now and in 5 years

Due to the military coup, it was not possible to assess any community impacts.

8.3.1 Economic impacts

Due to the military coup, it was not possible to assess any economic impacts.

8.3.2 Social impacts

Due to the military coup, it was not possible to assess any social impacts.

8.3.3 Environmental impacts

Field trials in 2020 indicated that implementation of hedgerows or living cover crops in maize fields could significantly reduce soil erosion without impacting maize yields. While the trials were limited to two sites and one season, the results suggest that improved environmental outcomes can be achieved through simple management practices. This has strong implications for the Inle Lake region, where tourism is a strong economic driver. Unfortunately, due to the military coup no longer-term investigations could be undertaken and no valid conclusions can be drawn.

8.4 Communication and dissemination activities

The project plan and proposed trials were explained to collaborating farmers in the Kalaw Township to ensure engagement with local farmers from the outset of the project. The farmer engagement meeting and field visits were coordinated by project staff member Tin Maung Aye, and included U Aung Zaw Moe (Head of Land Use Division, Shan State), U Myo Thein Tun (Deputy Staff Officer, Kalaw DoA Extension), Daw Thet Thet Aye (Kalaw Township Manager, DoA) and two Agriculture Graduates.

Figure 6 – Farmer engagement and planning meeting 2020

Following the military coup, all subsequent planned dissemination activities were abandoned.

9 Conclusions and recommendations

9.1 Conclusions

Field trials conducted in Kalaw Township area prior to the military coup showed promising results regarding minimising erosion while maintaining productivity through the use of hedgerows and/or cover crops. Field trials in Australia on similar undulating fields with high-P-fixing soil also indicated that the use of legumes in rotations (in place of fallows) had no negative impacts on maize yields but had potential to increase longer-term soil fertility. No strong conclusions could be drawn because of the limited number of trials that could be undertaken due to the military coup. Extensive training activities were not possible due to the military coup.

9.2 Recommendations

No recommendations for Shan State farmers could be developed because of the limited data obtained from research and demonstration trials.

Given the large potential for improvements in soil fertility and environmental outcomes in the Shan State, it is recommended that ACIAR consider bringing key individuals out of Myanmar (Shan state) into similar agroecological zones (e.g., NSW Northern Rivers [Australia] or Thailand) for training as a means of transferring knowledge to Myanmar.

10 References

10.1 References cited in report

FAO–UNESCO. (1974): Soil map of the world. Food and Agriculture Organization of the United Nations, Rome.

Jemo, M., Abaidoo, R. C., Nolte, C., Tchienkoua, M., Sanginga, N., Horst, W. J. (2006): Phosphorus benefits from grain-legume crops to subsequent maize grown on acid soils of southern Cameroon. Plant Soil 284, 385–397.

Vandamme, E., Pypers, P., Vanlauwe, B., Baijukya, F., Smolders, E. & Merckx, R. (2014). Residual phosphorus effects and nitrogen× phosphorus interactions in soybean–maize