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Intercropping of maize, millet, mustard, wheat and ginger increased land productivity and potential economic returns for smallholder terrace farmers in Nepal

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ABSTRACT

Low nitrogen inputs, low crop yield, and low land productivity are major challenges associated with cereal-based sole cropping systems in Nepal. Crop intensification and diversification by introducing legumes as intercrops could help alleviate these challenges. With the presence of diverse crops and cropping systems, particularly in hilly topographies, a range of intercrop options is required. We compared 10 intercrop combinations to native sole cropping systems in the mid-hills of Nepal for two cropping seasons (2015–2017) to identify the most productive and economic intercrop combinations for smallholder terrace agriculture. In the spring-summer season (i.e., mid-March to mid-July), cowpea (var. Makaibodi and Suryabodi) and bean were intercropped with maize in 1:1 rows, whereas soybean, blackgram, and horsegram were broadcast with millet (30:70 ratios) during the rainy-autumn season (i.e., mid-July to mid-November). Pea and lentil were used as pre-winter/winter intercrops (i.e., mid-November to mid-March) in mustard (30:70 ratios), while wheat was planted with pea. Ginger was planted with maize in 1:1 rows during the spring-summer season in which the maize rows were replaced by soybean and lentil during the rainy-autumn and pre-winter/winter season, respectively. Plots were analyzed for yields of individual crops as well as other agronomic indicators including land equivalent ratio (LER), total land output (TLO), harvest index (HI), and potential economic return.

Maize + cowpea var. Makaibodi appeared to be the most productive and economic intercrop combination for the spring-summer season (LER – 1.58 and TLO – 4.26 t ha^{-1}, 21% higher than the maize sole crop with an increase in potential economic return by 67%) whereas millet + soybean appeared to be the best combination for the rainy-autumn season (LER – 1.40 and TLO – 2.21 t ha^{-1}, 26% higher than the millet sole crop with a 288% increase in potential income). For the pre-winter/winter season, wheat + pea and mustard + pea combinations appeared to be productive (wheat + pea: LER – 1.31 and TLO – 2.90 t ha^{-1} i.e., 16% higher than sole wheat with a 54% increase in potential income; mustard + pea: LER – 1.36 and TLO – 2.14 t ha^{-1} i.e., 30% higher than sole mustard with a 15% increase in potential income). The year round intercrop system (i.e., ginger + maize-soybean) displayed a LER value of 2.45 with increased TLO (21.8 t ha^{-1} i.e., 2% higher compared to sole ginger) which increased potential economic return by 6%. We conclude that legume intercropping was a robust option across seasons and locations confirming that it could be a promising ecological practice for intensification of cereal-based sole cropping systems on smallholder terraces. Also, it is important to note that soybean and pea provided higher potential net income to farmers as sole crops compared to when they were grown with millet and wheat as intercrops, respectively. It is important that we promote these options to smallholder farmers and disseminate the advantages of legume integration on land productivity, soil fertility management, and income.

Abbreviations: HI, harvest index; LER, land equivalent ratios; LI-BIRD, Local Initiatives for Biodiversity, Research and Development (a Nepalese NGO); masl, meters above sea level; ppm, parts per million; SAKNepal, sustainable agriculture kits for Nepal (a Canadian-funded international development project); SOM, soil organic matter; TLO, total land output

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1. Introduction

The production challenges attributed to cereal-based sole cropping systems on terraces are related primarily to low yield and low land productivity often arising from inappropriate agronomic management strategies. Farming in these regions mainly involves low external input rainfed farming to maintain livelihoods that decrease soil organic matter while increasing soil erosion, loss of soil fertility, and acidification (Chapagain and Raizada, 2017a; Wymann von Dach et al., 2013; Chapagain and Gurung, 2010; Riley et al., 1990). In addition, farming in remote terraces involves cultivation on poor quality land, poor access to agricultural inputs and services, lack of mechanization, labour shortages, poverty, and illiteracy (Chapagain and Raizada, 2017a).

Improving land productivity is essential to meeting the increasing demands of food and forage in hillside and mountain communities in Nepal where the majority of farmers are subsistence, with an average land holding of 0.68 ha (CBS, 2011). These regions are characterized by highly variable land use systems (e.g., rainfed *Bari* system in upland and the *Khet* system in irrigated lowland) (Regmi and Zoebisch, 2004). Farmers in both of these regions grow cereals as their staple diet. They typically harvest 2–3 crops in a year in sequence, and their choice of crops and cropping system is determined by multiple drivers such as climate, soil type(s), topography, household needs, availability of agricultural inputs (e.g. seeds, fertilizers, etc.), labour, and local market opportunities (Chapagain and Raizada, 2017a; Riley et al., 1990).

The major crops grown in the rained *Bari* system include maize (*Zea mays* L.), finger millet (*Eleusine coracana* L.), wheat (*Triticum aestivum* L.), and/or mustard (*Brassica nigra* L.). These are grown as sole crops during the rainy-autumn (i.e., mid-July to mid-November), spring-summer (i.e., mid-March to mid-July), and pre-winter/winter seasons (i.e., mid-November to mid-March), respectively, while rice (*Oryza sativa* L.) is mainly grown in the *Khet* system. Legumes, such as cowpea (*Vigna ungiculata* L. Walp.), common bean (*Phaseolus vulgaris* L.), soybean (*Glycine max* L. Merr.), horsegram (*Macrotyloma uniflorum* Lam. Verdc.), blackgram (*Vigna mungo* L. Hepper), field pea (*Pisum sativum* L.), and lentil (*Lens culinaris* Medik.) are also grown in the upland *Bari* system depending on the season (Chapagain and Raizada, 2017a; Chapagain and Gurung, 2010). Ginger (*Zingiber officinale* Roscoe), which takes ~10 months to mature, is also a popular cash/spice crop in the *Bari* system.

The variable and vulnerable nature of the terrace cropping system can be addressed by providing farmers with a menu of diverse options that are compatible with the growing season and location, including intercropping (Chapagain and Raizada, 2017a, b). Intercropping is when two or more crops are planted together on the same land (Ofori and Stern, 1987). Intercropping can be in rows, mixed, relayed or in strips depending on the method and time of planting. Row intercropping is when two or more crops are planted together in rows while mixed intercropping refers to broadcasting (Chapagain, 2016, 2014; Chapagain and Riseman, 2015, 2014a,). Typically, intercrop components are from different species or families, with one crop of primary importance (e.g., food production) and the other crop primarily providing additional benefits (e.g., N_2 fixation from legume species). An effective intercrop combination is one that provides greater total yield on a piece of land and uses resources more efficiently than would otherwise if each crop was grown as a monoculture (Inal et al., 2007).

Intercropping is considered as a promising agronomic option for terrace intensification that enhances productivity and environmental sustainability in upland (i.e., rainfed *Bari* system) as well as irrigated lowland (i.e., *Khet* system where legumes can be relayed with rice) regions (Chapagain and Raizada, 2017a). A few studies in the mid-hills of Nepal (e.g., Prasad and Brook, 2005; Subedi, 1997) have demonstrated that intercrops offer higher efficiency and economic returns than sole crops, but to enable wider adoption, farmers in this system should have a diversity of intercrop options that have been scientifically validated. In Nepal, some legumes such as cowpea, beans, and pea are grown as intercrops with maize, wheat or mustard; however, the productivity and potential economic return of each intercrop are not based or backed up by systematic on-farm research (Chapagain and Raizada, 2017a).

The current study evaluates the opportunities of using legumes as intercrops into maize, millet, wheat, mustard, and ginger to provide farmers in the mid-hills of Nepal with a menu of the most productive and economically profitable intercrop combination(s) for different growing seasons and household needs.

2. Materials and methods

2.1. Study site, climate and soil description

This study was conducted in two mid-hill districts of Nepal namely, Dhading and Kaski, for two cropping seasons from 2015 to 2017. The experimental sites in Dhading were located at 27° 78′ 84″ N and 84° 70′ 02″ E, at an altitude of 700–1300 m above sea level (masl) while the sites in Kaski were situated at 28° 20′ 25″ N and 84° 11′ 71″ E, at an altitude of 1100 masl. Research was conducted on farmers' fields under natural climatic conditions.

Climatic data for the experiment were collected from a regional weather station at the research site (Fig. 1). Average day-time temperature over the three cropping seasons (April–July, August–November and December–March) were 27.8 °C, 23.5 °C, and 18.3 °C in Dhading and 24.4 °C, 21.9 °C, and 16.3 °C in Kaski with the warmest days in May through August at both sites. Both Dhading and Kaski received more rainfall (annual total of 2660 mm and 3459 mm, respectively) in 2016 in comparison with 2015, with season 1 (i.e., April–-July) receiving the most (1408 mm and 1758 mm, respectively). Both sites received the least rainfall in pre-winter/winter (October through February), with no rains in November–December (Fig. 1).

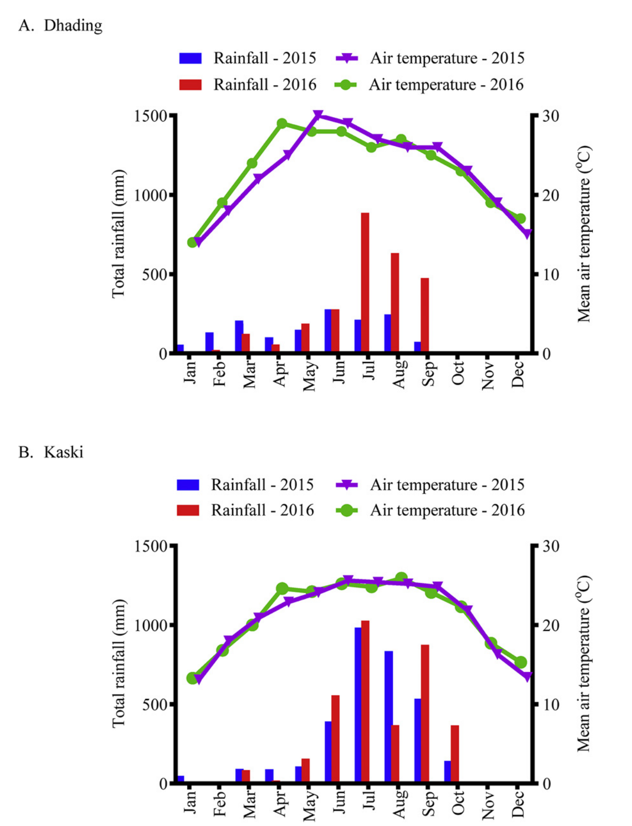

Fig. 1. Climatic data (air temperature and rainfall) collected for (A) Dhading and (B) Kaski districts in 2015 and 2016.