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SOIL & CROP SCIENCES | RESEARCH ARTICLE

Climate-smart practices for improvement of crop yields in mid-hills of Nepal

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Reviewing editor:
Manuel Tejada Moral, University of Seville, Spain

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Abstract: Farming in Nepal mostly represents the hill farming system with the dominance of small-holder farmers. In recent days, farmers in the country are impacted by climate change. Events of surface runoff, landslides, and soil erosions, along with changes in rainfall pattern and intensity have elevated a decline in crop productivity and soil fertility. Considering the situation, a pilot project on Resilient Mountain Village was implemented in Kavrepalanchowk district of Nepal from 2014–2016 with a participatory approach to demonstrate climate-smart practices. These practices include the application of locally prepared bio-fertilizer (named as "jholmal"), green manuring in rice (*Oryza sativa* L.) and mulching in bitter-gourd (*Momordica charantia* L.) to determine crop yields compared to farmers' business as usual practice. The results showed that there was a significant effect of jholmal in rice production during 2015–2016 when compared to farmers' business as usual practice. Likewise, green manuring also showed a significant difference in rice yield compared to farmers' usual practice in 2015–2016. Bitter-gourd yields were significantly higher in mulching treatment compared to the farmers' business as usual practice in 2015 and 2016. Rice yield increased by at least 10.1% and 8.1% while using jholmal and green manuring, respectively, whereas bitter-gourd yield

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PUBLIC INTEREST STATEMENT

Nepal is a mountainous country where hill farming system is dominantly practiced. In recent days, climate change has impacted agriculture and thus affected the livelihood of people depending on agriculture. Rainfall has been unpredictable, temperature is rising, extreme weather events such as flood, drought, and water scarcity are impacting the food production system. Adaptation at a local level is necessary to adjust to the changing scenario. Resilient Mountain Village, an integrated approach that combines social, economic, and environmental dimensions of sustainable development with climate change adaptation, resilience, and preparedness to future risks. It aims to test, demonstrate, and disseminate simple, affordable, and replicable climate-smart practices. This paper aims to bring results from eight villages of Kavre district to scale out the adaptive technologies. The results can be beneficial in planning for adaptation measures to smallholder farmers residing in the mountain region.

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increased by 18.1% with mulching practices. Our findings show that farmers have adopted these practices and minimized the use of chemical fertilizers and pesticides, thus moving forward to producing safer food using a climate-friendly approach.

1. Introduction

Hill farming system in Nepal represents 40% of cultivated land predominantly practiced by smallholder farmers (Paudel, Tamang, Lamsal, & Paudel, 2011). In recent days, farmers in the country are impacted by climate change (Paudel, 2010). Events of surface runoff, landslides, and erosions are exacerbated by changing climate scenario and have been observed in many parts of the country affecting the crop yields (Agarwal et al., 2000; Panday, 2012).

The intergovernmental panel on climate change (IPCC) projected a severe impact on the mountain ecosystem due to climate change, largely impacting vulnerable and smallholder farmers (Intergovernmental Panel on Climate Change [IPCC], 2007). A recent assessment in the Hindu Kush Himalaya (HKH) revealed significant warming projection in the region over the 21st century. The temperature across the mountainous region in the HKH is projected to increase by 1–2°C or in some places up to 4–5°C by 2050, which is greater than the global average (Shrestha et al., 2015). Likewise, the projection of rainfall showed that the summer monsoon is likely to increase by 4–12% in a short run whereas by 4–25% in a longer term, however with regional variability across the HKH (Wester, Mishra, Mukherji, & Shrestha, 2019). In Nepal, the impacts of changing weather pattern are well discussed for mountain smallholder farmers (Gentle & Maraseni, 2012; Rai, Bhatta, Acharya, & Bhatta, 2018). Since, agriculture primarily relies on climatic conditions, climatic variability may have negative impacts on agro-ecosystem, increasing risks of pests and diseases, and altering nutrient cycle and soil moisture (Fuhrer, 2003; Jones & Thornton, 2003). Likewise, erratic rainfall, extreme weather events such as flood, and drought, water scarcity largely impact on food production, and other associated ecosystem services (Bhatta, van Oort, Stork, & Baral, 2015). Charmakar (2010) discussed the change in forest-agriculture-based livelihood strategies due to changing rainfall pattern and a prolonged drought period. Further, Paudel (2013) revealed an increase of pest and diseases in mountain agriculture, ultimately impacting on yields.

In addition, changing farming practices in recent days, with less interest to practice in-situ manuring, green manuring, and other traditional practices linking to livestock, forest and cropping systems have adversely affected crop production and soil fertility status (Pilbeam, Mathema, Gregory, & Shakya, 2005; Tiwari, Sitaula, Nyborg, & Paudel, 2008). The region also faces increasing male outmigration to seek a better job and income opportunities, e.g., in the Koshi River Basin of Nepal, there was at least one migrant in 38.6% of households out-migrated mostly international (Hussain, Rasul, Mahapatra, & Tuladhar, 2016). This has increased women drudgery, making them responsible also to manage agriculture and natural resources. On the other hand, growing population, changing food habit, and market opportunities have increased land intensification in the hilly regions to meet the increasing food demand which resulted to decline in soil fertility and low crop productivity, especially in peri-urban areas (Bhatta & Doppler, 2011). The use of chemical fertilizer has hence, dramatically increased from a national average of 16.7 kg ha^{-1} in 2002 to 67.4 kg ha^{-1} in 2014 (CBS, 2013). However, the promotion of chemical fertilizers in hills and mountains is not beneficial as the return to investments for smallholders having the land occupancy of 0.05 ha are

relatively lower compared to plains (Terai), where farmers own medium to large size farms (Takeshima, Adhikari, Kaphle, Shivakoti, & Kumar, 2016).

To address the above-mentioned complex drivers of socio-economic changes including the impacts of climate change in the agriculture sector, climate-smart practices were promoted through Resilient Mountain Village (RMV) project in 2014 among the smallholder farmers in Kavrepalanchowk (hereafter Kavre) district. RMV is an integrated approach that combines social, economic, and environmental dimensions of sustainable development with climate change adaptation, resilience, and preparedness to future risks. It aims to test, demonstrate and disseminate simple, affordable and replicable climate-smart practices among the smallholder farmers in Kavre district for wider out-and-up scaling. The elements of climate-smart practices in agriculture were adopted from Climate-Smart Agriculture (CSA) approach developed by the Food and Agriculture Organization (FAO) and Climate-Smart Villages (CSV), an adoption of CSA by the Consultative Group on Integrated Agriculture Research (CGIAR) aiming to foster sustainable development and food security in a changing climate context (CCAFS & CIMMYT, 2014; FAO, 2013).

The climate-smart agriculture practices aim to increase agricultural productivity and incomes of farmers, strengthen adaptive capacity and build resilience to climate change, and reduce greenhouse gases emissions where possible. This include water-smart practices (that increase water availability through water harvesting, storage, source protection and its efficient use), soil-smart practices (that improve soil health through safe farm inputs, stabilize soil erosion and reduce nutrient leaching), crop-smart practices (that promote multiple cropping, crop rotation, and use of local or climate tolerant varieties), information and communications technology, and crop and livestock insurance (CIAT, World Bank, CCAFS and LI-BIRD, 2017). This paper, however, highlights three major treatments contributing to soil and water-smart agriculture practices through the application of jholmal (home-made bio-fertilizer and also used as bio-pesticide), mulching, and green manuring as adaptive measures for smallholders (ICIMOD, 2016). Smith et al. (2007) suggested using these practices to be potential mitigation measures apart from strengthening the adaptive capacity of the smallholders.

This paper mainly presents a comparative assessment of different crop varieties using three different treatments-jholmal, green manuring, and mulching compared to the farmers' locally used business as usual practices from the experimental trials in 2015 and 2016. The details on the business as usual practice of the farmers are described in the methods section while describing the above three treatments.

2. Materials and methods

2.1. Study area
Kavre district is 30 km east from the capital city, Kathmandu, Nepal. It represents one of the mid-hill districts in Nepal and is well known for its agriculture practices like growing and supplying cereals, potatoes, and vegetables to the capital city. In 2014, the RMV project piloted its intervention in four villages of Kavre: Mahadevsthan Mandan (MM), Nayagaun-Deupur (ND), Kalchhebesi (KB), and Patlekhet (PK), and later in 2015, the project was extended to an additional four villages: Rabi (RB), Opi (OP), Baluwa (BA), and Bela (BE) (Figure 1). The eight pilot sites were selected along the altitudinal gradient to capture the heterogeneous geography in the mid-hills of Nepal; therefore, they represent the top hills with altitude ranging from 1227 to 1400 masl and the foothills with altitude from 878 to 968 masl (Table 1). Altogether, there were 1089 households selected in a participatory way within the eight villages, organized in 40 different groups to pilot the climate-smart agriculture practices (ICIMOD, 2016).

The climate in the study area is mostly sub-tropical, consisting mid-altitude ranges and river bank valleys. Meteorological data from the nearby Dhulikhel station showed an average annual temperature of 9.1°C in January and 21.7°C in June, depending upon the altitude. The area

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Figure 1. Study area for Resilient Mountain Village project in Kavre district of Nepal.

(Source: ICIMOD).

Resilient Mountain Villages – Himalayan Climate Change Adaptation Programme
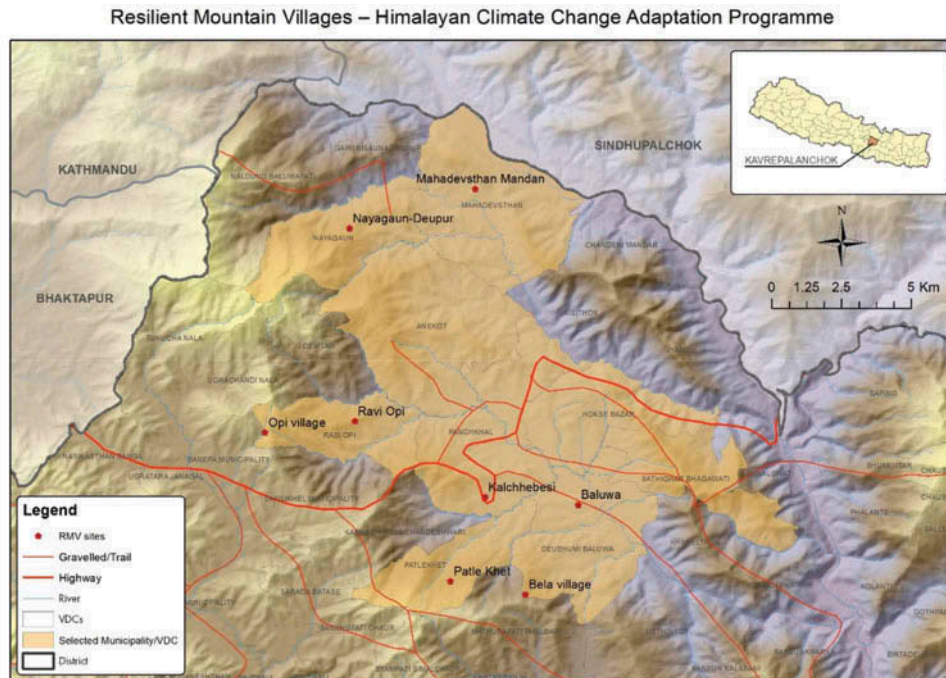
Table 1. The pilot sites of Resilient Mountain Village project in Kavre district of Nepal				
S. N.	Name of Pilot Site	Altitude (masl)	Agro-ecological Zone	Soil types
1	Patlekhet (PK)	1305	Top Hills	Loam
2	Kalchhebesi (KB)	968	Foot Hills	Loam and sandy clay loam
3	Rabi (RB)	895	Foot Hills	Sandy loam and loam
4	Opi (OP)	1400	Top Hills	Loam and sandy loam
5	Mahadevsthan Mandan (MM)	885	Foot Hills	Loam and sandy loam
6	Nayagaun-Deupur (ND)	1227	Top Hills	Loam and sandy loam
7	Baluwa (BA)	878	Foot Hills	Loam and sandy loam
8	Bela (BE)	1300	Top Hills	Loam

received around 1500–2000 mm of rainfall annually, which range from an average 7 mm rainfall in December to average of 444 mm in July.

2.2. Experimental design for the climate-smart practices

Three different climate-smart agriculture practices, namely jholmal application in rice, green manuring in rice and mulching in bitter gourd were demonstrated among the lead farmers in Kavre district. Farmers for experiment were selected on the basis of the agro-ecological zone for the representation of foothills and top hills. In each site, lead farmers from the farmers' group were selected through group meeting to conduct trials. The experimental trials for each of the three treatments and the respective control trails with business as usual practices included at least

three replications for each site in each crop (i.e., n equals to farmers having both experimental and control trails as replication for each crop). The experimental and control trials for all treatment types were established adjacent to each other to maintain homogenous site quality, slope, and aspect, whereas the potential site heterogeneity if any within and between the trails were neglected. The details on each treatment type along with the experimental design are elaborated below-

2.2.1. Jholmal

Jholmal is a homemade bio-fertilizer, also used as bio-pesticide prepared by mixing farmyard manure (FYM), animal urine, water, and plants having insect repellent properties in a defined ratio (Subedi, 2016). Jholmal is physically in a liquid state when prepared which is applied after diluting with water. There are three types of jholmal, namely, jholmal-1, jholmal-2, and jholmal-3 prepared and applied to the crops (Table 2). The pH and nutrient content (N, P, K) of different jholmal types is given in Table 3.

Jholmal application and its effect on yield of various crops such as rapeseed (*Brassica napus* L.), potato (*Solanum tuberosum* L.), rice (*Oryza sativa* L.), cauliflower (*Brassica oleracea* var. *botrytis*) were studied during the RMV pilot project in Kavre from 2014 to 2016. However, this paper includes the application of jholmal in rice production from 2015–2016 only. The growing season for rice was during June–July when the rainy season was onset. Nursery for rice was grown during pre-monsoon showers that is one month earlier the transplanting begins. This is normal rice growing season in Nepal. Altogether 37 farmers from the 8 eight project sites participated for conducting jholmal trial in rice, where Khumal-4 variety was selected for top hills, and Makawanpur-1 variety for foothills. For top hills 18 farmers and for foothills 19 farmers were selected on the basis of agro-ecological zones for rice growing areas and farmer's willingness to conduct the trials.

Table 2. The preparation method and application of various Jholmal-1, 2, and 3		
Jholmal Type	**Preparation Method**	**Application Method**
Jholmal-1	Prepared from mixing FYM, animal urine, and water in equal proportion mixed thoroughly and kept in a plastic jar for 15 days.	Jholmal is ready to be applied after 15 days by diluting in 3–6 L water. Younger plants need more dilution while 3 L of water dilutions is done as plants get older
Jholmal-2	Prepared from mixing animal urine and water in equal proportion mixed thoroughly and kept in a plastic jar for 15 days.	Jholmal is ready to be applied after 15 days by diluting in 3–6 L water. Younger plants need more dilution while 3 L of water dilutions is done as plants get older
Jholmal-3	Prepared from mixing animal urine, water and chopped leaves of plants with properties of animal repellent and killing. The mixture is placed in plastic jars filled with water and urine and left from 25–30 days depending upon the temperature.	Jholmal is ready to be applied after 25–30 days by diluting in 3–6 L water. Younger plants need more dilution while 3 L of water dilutions is done as plants get older

Table 3. The pH and nutrient content in jholmal					
Jholmal types	**pH**	**Organic carbon (%)**	**Nitrogen (N) (mg g^{-1})**	**Phosphorus (P) (mg g^{-1})**	**Potassium (K) (mg mL^{-1})**
Jholmal-1	8.1	1.7	1.3	0.1	0.2
Jholmal-2	7.7	0.1	0.3	0.1	0.1
Jholmal-3	6.7	0.5	0.3	0.2	0.1

The jholmal treatment was applied systematically in the experimental trails using 24 L jholmal-1 plus 36 L jholmal-2 plus 24 L jholmal-3 plus 600 kg FYM per 500 m² area. For control trials, the business as usual fertilizer application common in rice farming was considered as local farmers' practice. The farmers' local practice included using 4.5 kg N (equivalent to 9.8 kg urea) plus 2.8 kg P_2O_5 (equivalent to 6 kg di-ammonium phosphate or DAP) plus 2 kg K_2O (equivalent to 3.3 kg muriate of potash or MOP) plus 600 kg FYM per 500 m² area.

To assure the availability of nutrients during rice cultivation in critical growth stages, the Jholmal treatment in experimental trails was applied in four split doses. First, after seven days of transplanting, and the second, third, and fourth doses at 15 days interval over the rice growing season. Likewise, the farmers' local practice in the control trails included urea application in two splits, i.e., first after 30 days of transplanting and second after 45–50 days of transplanting, whereas other fertilizers (FYM, DAP, and MOP) were applied as basal doses.

The harvesting of rice from the experimental and control trials was done at its maturity, which was judged by hard and yellow colored grains, and golden yellowing of leaves. From each trial, three samples were taken from 1 m² area which was later averaged to record the yield. Samples were taken from the representative areas leaving two rows (equivalent to 40 cm) of plants from all the four sides to avoid border effect. The rice plants were cut with a sickle and left to dry for a few days. After 3–4 days of drying, threshing was done manually, and the rice grains were measured by digital weighing balance to record yield.

2.2.2. Green manuring

Experimental trials for the effect of green manure in rice were conducted during 2015 and 2016 using Sesbania (*Sesbania rostrata*). In 2015, six lead farmers were chosen from two pilot sites in the foothills of the rice growing areas. While in 2016, 24 lead farmers were chosen from eight pilot sites at both top hills and foothills. For the experiment, rice variety, Khumal-4 was selected in the top hills whereas Makawanpur-1 in the foothills. The field trials were divided into two equal halves, 125 m² each, and in one half of the trial, Sesbania was planted 45 days earlier before rice transplantation. Rice transplantation was done two days after green manure was incorporated in the soil.

Sesbania was sowed at 30 kg ha⁻¹ ratio in 125 m² green manure trial, and no external fertilizer was added. In the business as usual farmers' practice, which is 125 m² control trail 11–14 Mt ha⁻¹ of FYM, 59–70 kg N ha⁻¹ (equivalent to 128–152 kg urea ha⁻¹) and 40–46 kg P_2O_5 ha⁻¹ (equivalent to 85–99 kg DAP ha⁻¹) was applied. The farmers' business as usual practice included the application of urea in two splits, i.e., first after 30 days of transplanting and second after 45–50 days of transplanting. Other fertilizers (FYM and DAP) were applied as a basal dose. The yield determination is similar to the process described in jholmal treatment.

2.3. Mulching

Mulching involves covering plants with dried paddy straw and is extensively used during dry seasons to retain moisture and provide conducive temperature for crop growth (Subedi & Basnet, 2016). It is not a new practice in agriculture but, was promoted as one of the climate-smart practices that support water retention in soil, decrease evapotranspiration and also controls temperature fluctuation in soils providing plants to grow in a conducive environment (Mulumba & Lal, 2008; FAO, 2013).

Mulching is particularly suitable in the study area for early spring season vegetables before the pre-monsoon starts when there is limited water availability. The experiment was conducted during 2015 and 2016. Initially, project was implemented in four sites, therefore only 12 lead farmers from foothills participated in spring season of 2015 while 25 lead farmers from 8 different sites participated in 2016. Straw mulching was used in the experimental trails after transplanting in

bitter gourd (*Momordica charantia* L.) plants, whereas in the business as usual farmers' practice the topsoil of the control trails was left uncovered.

As bitter-gourd is a multiple harvesting crop, the farmers' experience judged the maturity of each fruit to measure the total yield. Farmers harvested the fruit according to the size and physical appearance of light green to green. It was made sure that the harvesting was done before the fruits ripe or get yellowish. Later, yields were recorded at each harvest by the lead farmers in close supervision of the agriculture technician working at the pilot sites.

The growing season for bitter-gourd was during February–March. The time is spring season and is normally dry with very rare rain and temperature increasing. The practices like mulching were promoted to protect crop from drying and saving water from evapotranspiration loss.

2.4. Meteorological stations
The RMV project established three meteorological stations during 2014 in collaboration with public schools. Weather data, including minimum and maximum temperature, precipitation and relative humidity were recorded manually on a daily basis. In this manuscript, we included data from two stations, one stationed at the foothill and another at the top hill. The altitude and location of the meteorological stations are presented in Table 4.

2.5. Data analysis
Yield data from the experimental and farmers' field locations were extrapolated in per hectare area and mentioned in ton per hectare. The effects of the major three treatment types on crop yield from the experimental and control trials were analyzed using paired *t*-test in SAS software. Location-wise mean crop yields were separated using least square means for each treatment. Significant differences of treatments were stated at 95% confidence interval.

The climate data collected from Mahadevstan Mandan (MM) represented foothill and Patlekhet (PK) represented the top hill to analyze the variation in weather patterns during the growing season. The daily data were averaged to monthly maximum and minimum temperature, while total rainfall received was summed up for each month at each meteorological station.

3. Results and discussion

3.1. Weather condition during the growing season
The temperature trend in the foothill showed lowest monthly average minimum temperature of about 7°C during December in 2015 and in January 2016, while the highest monthly average maximum temperature was about 33°C during May in 2015 and about 35°C in August 2016. At the top hill, the lowest monthly average minimum temperature was about 5°C during January 2015 and about 8°C in January 2016, while the highest monthly average maximum temperature was about 32°C during June in 2015 and about 30°C during April in 2016. This temperature scenario represented mid-hill situation of Nepal where summers are hot with maximum temperature

Table 4. Meteorological Stations in various agro-ecological zone in Kavre			
Name of Meteorological stations	**Altitude (masl)**	**Location**	**Agro-ecological Zone**
Shree Dedithumka Higher Secondary School, Mahadevstan	885	27°43'08.8"N 85°37'02.6"E	Foot hill
Shree Hanuman Higher Secondary School, Patlekhet	1305	27°35'36.8"N 85°35'20.1"E	Top hill

exceeding 25°C and cold winters (Shrestha, 2012). Usually, in Nepal, the temperature is lowest from December to January, while May and June are the hottest months (DHM, 2015).

The rainfall pattern showed peak rainfall during August and June in 2015 and 2016, respectively, at foothill region. The rainfall pattern at the top hill region showed peak rainfall during August in 2015 while during 2016 the peak rainfall was in June. The rainfall pattern during both years in the study sites showed that more than 80.2% of rainfall showered in between June and September (Figure 2). The rainfall pattern showed that winter and spring seasons are drier and for smallholder farmers, water management is challenging in this period. Practices like straw mulching can be thus applied during winter and spring season to prevent evapotranspiration loss from the soil. Mulching conserves soil moisture and provides a conducive environment to plants by reducing the temperature fluctuation in soil (Mulumba & Lal, 2008).

3.2. Effects of jholmal on rice yield
A significant difference in rice yield was observed due to the effect of jholmal. Rice yields were higher by 15.5% in jholmal experimental trails compared to the control during 2015 whereas, in 2016 the rice yield increased by 10.6% compared to the control trails (Table 5). The difference in the increased percentage of rice yield during 2015 and 2016 may be referred to the lower number of sample size in 2015 (n = 12) from only four pilot sites compared to the sample from eight sites in 2016 (n = 25). Since inferential statistics makes predictions based on the sample size of the given population, the larger the sample size, more reliable is the result although the cost and time to

Figure 2. Study area monthly maximum and minimum temperatures and rainfall in top hills (Location: Patlekhet) and foothills (Location: Mahadevsthan Mandan) from 2015 to 2016. Alphabets in X-axis represent short form of the month (such as J for January, F for February, etc.).
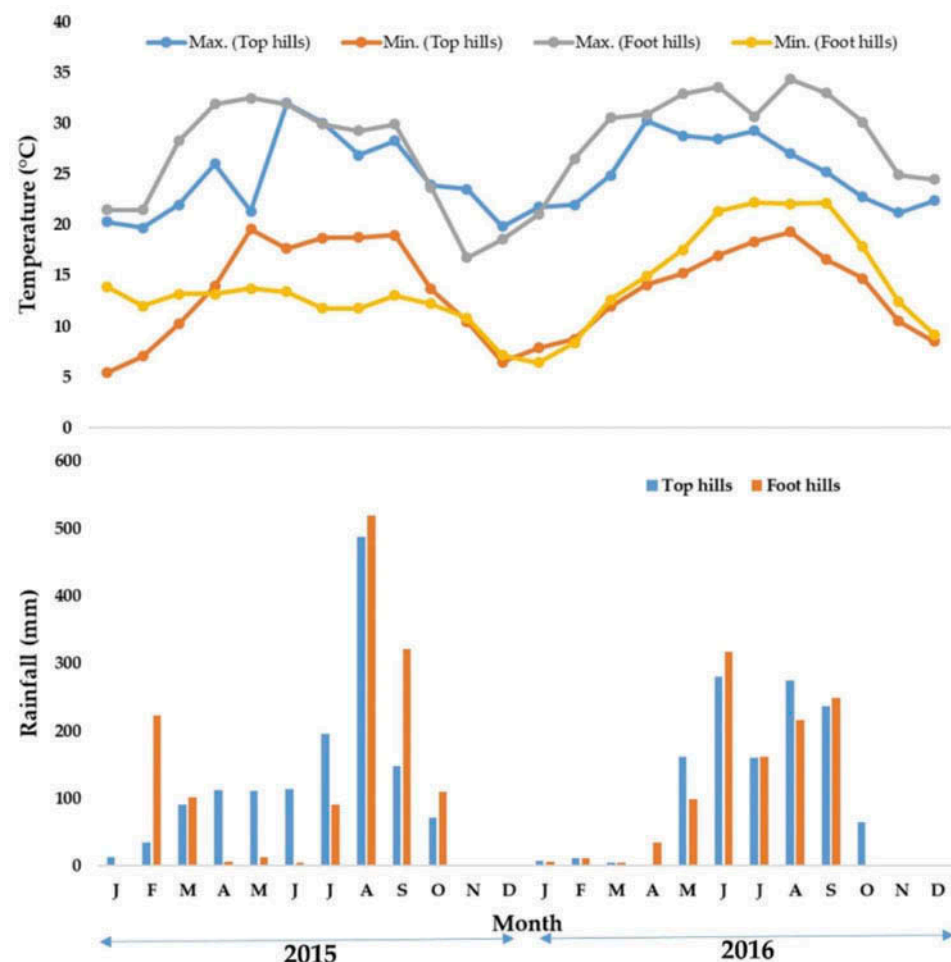
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Table 5. Paired *t*-test for the effects of major treatments on crop yields in Kavre district of Nepal		
Treatment	**Yield, t ha^{-1}**	
	2015	**2016**
1. Jholmal (in rice)		
Jholmal	5.2 (n = 12)	5.2 (n = 25)
No jholmal	4.5	4.7
Significance	**	**
2. Green manuring (in rice)		
Green manure	5.3 (n = 6)	4.5 (n = 24)
No green manure	4.9	4.1
Significance	*	NS
3. Mulching (in bitter gourd)		
Mulching	18.1 (n = 12)	18.2 (n = 25)
No mulching	15.3	15.4
Significance	*	**

**$P < 0.01$, *$P < 0.05$, NS = not significant

No jholmal, no green manure, and no mulching are the control treatments against application of jholmal, green manure, and mulching, respectively. These control treatments define farmers' business as usual practice in the study area.

increase the sample size is often high. The results of 2015 and 2016, showed that the jholmal treatment has a positive effect on rice yield compared to the business as usual farmers' practice in Kavre district. Figures 3 and 4 revealed an increase in rice yield to jholmal application in all the sites in both the years compared to the control trails.

On the other hand, among the four pilot sites experimented in 2015, the highest rice yield of 6.2 t ha^{-1} was observed in Mahadevstan Mandan (MM), followed by Nayagaun Deupur (ND) when jholmal was applied (Figure 3). Likewise in 2016, the highest rice yield was recorded to be 6.7 t ha^{-1}, in Kalchhebesi (KB) under jholmal treatment, which is 19.2% increase compared to the farmers' usual practice (Figure 4). In both years, the rice yield was found to be higher in those sites that are in the foothills, this might be due to the higher production capacity of Makawanpur-1 variety, given the suitable growing conditions in the foothills and river basins.

While considering an increase in crop production and improvement in soil health, environment aspects from soil degradation and its management cannot be ignored because there is a strong impact in global carbon cycle due to nutrient input and soil erosion (Lal, 2003; Panday, Maharjan, Chalise, Shrestha, & Twanabasu, 2018). Soil nutrient depletion may result in yield loss and cause a threat to food security of marginalized people living in sloppy terrains (Tan, Lal, & Wiebe, 2005). In the current study, the yield increments (up to 10–20%) as a result of jholmal use can be attributed, but not limited to the increased availability of manure-N due to anaerobic digestion of liquid manure (Webb et al., 2013). The increase in crop yield due to the application of jholmal may be as a result of the faster supply of nutrient with foliar application that supplement plant growth by overcoming temporary nutrient deficiencies (Gajjela, Chatterjee, Subba, & Sen, 2018). Similarly, increased activities of growth promoting bacteria contained in jholmal may also increase nitrogen fixation in soil, induce growth hormone production and control pathogens to enhance the crop growth (Rakesh, Poonguzhali, Saranya, Suguna, & Jothibasu, 2017).

Further, there is an increased interest among the farmers towards jholmal use as it can be produced at home, and moreover, this practice is getting popular among women farmers (Agrawal, Bhatta, Gjerdi, & Joshi, 2018) and 138 farmers immediately adopted this technology after few demonstrations. The farmers used jholmal as bio-fertilizer and applied for crop

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Figure 3. Effects of jholmal/no jholmal on rice yield (mean ± standard error) in 2015 in four different sites: Mahadevstan Mandan (MM), Nayagaun-Deupur (ND), Kalchhebesi (KB), and Patlekhet (PK).
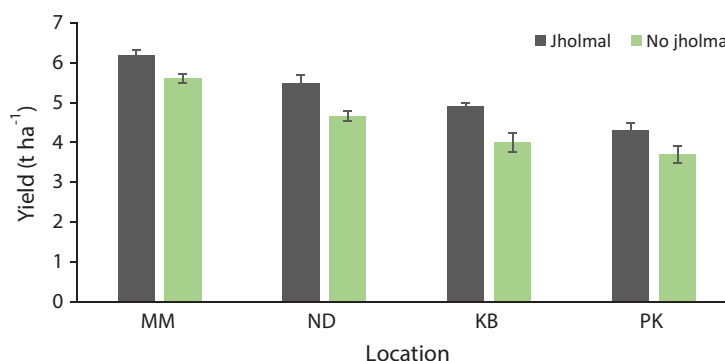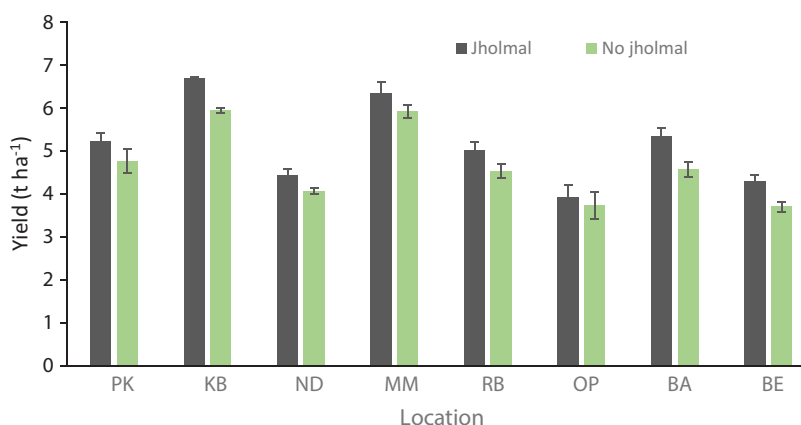

Figure 4. Effects of jholmal/no jholmal on rice yield (mean ± standard error) in 2016 in eight different sites: Patlekhet (PK), Kalchhebesi (KB), Nayagaun-Deupur (ND), Mahadevsthan Mandan (MM), Rabi (RB), Opi (OP), Baluwa (BA), and Bela (BE).

production as an alternative to chemical fertilizer. By this, it is also reducing dependency on the external inputs (e.g., purchase of chemical fertilizers), thus increasing their adaptive capacity to build resilience at a community level (Bayleyegn et al, 2018; Gurung, Basnet, Paudel, Chaudhary, & Bhatta, 2017).

3.3. Effects of green manuring on rice yield

Practices like green manuring and organic compost addition have shown a positive impact on soil by improving physical properties, especially increasing soil moisture in rainfed farming, reducing the erosion and making cropping system more resilient (Borthakur, Tivelli, & Purquerio, 2012). The analysis of effect of green manuring on rice yield during 2015 showed a significant difference with 8.1% higher yield compared to farmers' usual practice in the control trial (Table 5). The rice yield was highest at Mahadevstan Mandan (MM) in 2015 with 5.6 t ha^{-1} yield produced by applying green manure (Figure 5). However, no significant difference in rice yield was observed in 2016 due to green manuring. This might be because of the variation observed due to increased rice yield due to green manuring at six sites, whereas at other two sites (Bela and Opi) the farmers' usual practice surpassed the rice yield (Figure 6). The reason for lower rice yield when applying green manuring at the two sites might be because of the lesser decomposition rate at the top hills with limitation of water and temperature.

Nevertheless, an experiment on green manure (*Sesbania rostrate*) by Latt, Myint, Yamakawa, and Ogata (2009) in Myanmar showed that green manuring could produce higher rice yield compared to the urea-N application of 40 and 80 kg N ha^{-1}. Green manuring is one of the recommended climate-smart agricultural practices for smallholders, who mostly avoid buying external inputs and resources owing to their low affordability (Gurung et al., 2017). Besides, green manuring is taken as soil-smart practice or climate adaptive practice, which equally has mitigation potential (FAO, 2013). The

Figure 5. Effects of green man-uring/no green manuring on rice yield (mean ± standard error) in 2015 in two different sites: Mahadevstan Mandan (MM) and Kalchhebesi (KB).
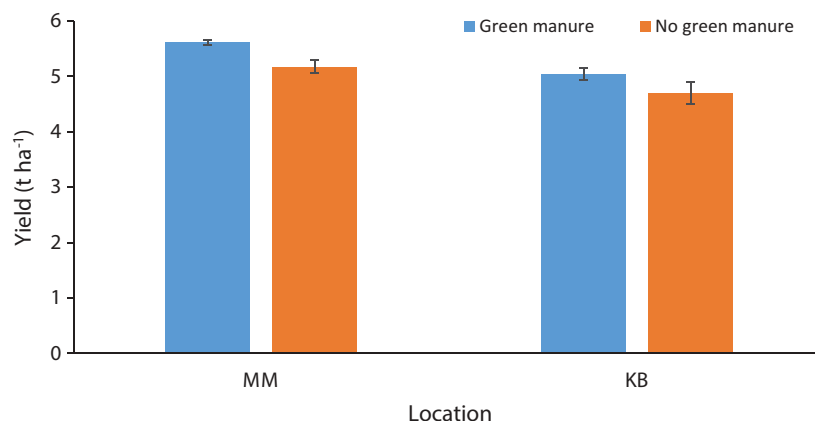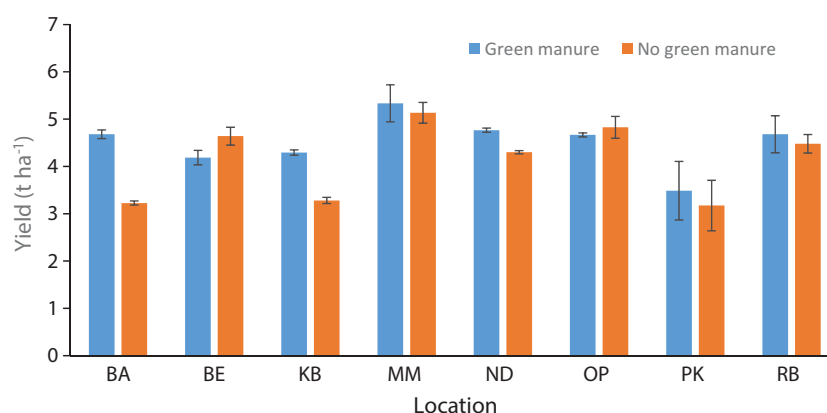

Figure 6. Effects of green man-uring/no green manuring on rice yield (mean ± standard error) in 2016 in eight different sites: Baluwa (BA), Bela (BE), Kalchhebesi (KB), Mahadevsthan Mandan (MM), Nayagaun-Deupur (ND), Opi (OP), Patlekhet (PK), and Rabi (RB).

promotion of green manuring in rice can benefit the smallholders by reducing the cost of rice production as well as foster sustainability and resilience of the farm systems.

3.4. Effects of mulching on bitter-gourd yield

A significant difference on bitter-gourd yield was observed with increase in bitter-gourd yields by 18.3% in 2015 and 18.1% in 2016 due to the effect of mulching compared to the farmers' business as usual practice (Table 5). Among the pilot sites from 2015 and 2016, the highest bitter-gourd yield of 22.0 t ha^{-1} and 22.8 t ha^{-1}, respectively, was recorded from Mahadevstan Mandan (MM) under the straw mulching treatment (Figures 7 and 8). Likewise, the lowest bitter-gourd yields were recorded under farmer's usual practice in control treatment of Baluwa and Bela sites.

Mulching is one of the most popularly adopted practices during the RMV project. Farmers were attracted towards mulching practice as they could save water and labor expenses (Subedi & Basnet, 2016) from growing bitter-gourd during the early spring season when there is less water available for irrigation.

4. Conclusion

The paper discussed three major climate-smart practices: application of jholmal, green manure, and mulching that has been introduced through RMV Project among the smallholder farmers in the mid-hills region of Nepal. The project was successful in introducing various low cost, simple and affordable practices to the smallholder farmers in Kavre to keep their agricultural yield high and at the same time supporting to minimize the cost of production by using locally available resources

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Figure 7. Effect of mulching/no mulching on bitter-gourd yield (mean ± standard error) in 2015 in six different sites: Mahadevsthan Mandan (MM), Nayagaun-Deupur (ND), Kalchhebesi (KB), RabiOpi (RO), Bela (BE), and Baluwa (BA).
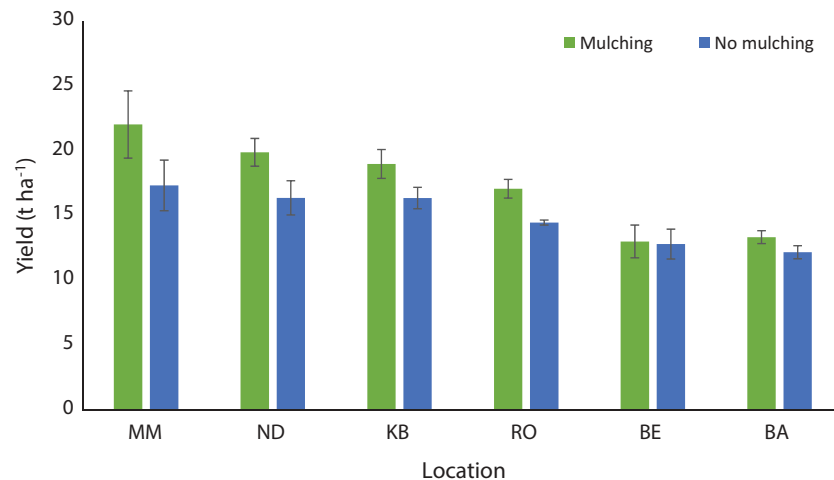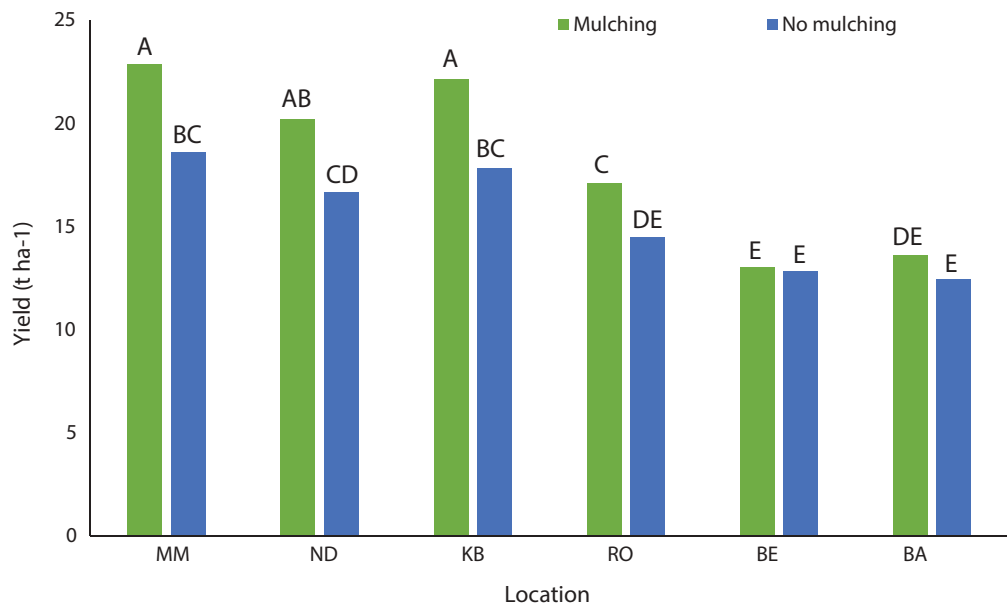

Figure 8. Effect of mulching/no mulching on bitter-gourd yield in 2016 in six different sites: Mahadevsthan Mandan (MM), Nayagaun-Deupur (ND), Kalchhebesi (KB), RabiOpi (RO), Bela (BE), and Baluwa (BA). M stands mulching and NM for no mulching practice. Average yield with the same letter among the sites is not significantly (p < 0.001, LSD) different by treatments.

that can be prepared at home. The results from three major climate-smart practices piloted in the study area showed higher crop yields compared to farmers' business as usual practice that attracted many farmers to adopt such practices, for example, 138 farmers from the vicinity of the study area adopted jholmal, and gradually changing their agriculture system towards organic agriculture, using less chemical and producing safe food. The promotion of jholmal also contributes towards integrated agriculture, where livestock and agroforestry components have to be combined as jholmal requires animal urine and locally available plant materials as a major constituent. Our study showed a positive result in terms of production using different climate-smart practices. However, there is still a need of further research on these practices to understand the effects on productivity of different crops and impacts to soil health (soil nutrient, soil texture, pH, water holding capacity) at different agro-ecological regions.

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Competing Interests
The authors declare no competing interests.

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Conflicts of Interest
The authors declare no conflict of interest.

Disclaimer
This study was undertaken by the Himalayan Climate Change Adaptation Program (HICAP) at the International Centre for Integrated Mountain Development (ICIMOD). HICAP was implemented jointly by ICIMOD, CICERO, and Grid-Arendal in collaboration with local partner, CEAPRED in Kavre, Nepal. The views and interpretations in this publication are those of the authors and should not be attributed to ICIMOD, HICAP, CEAPRED or the donors.

Citation information
Cite this article as: Climate-smart practices for improvement of crop yields in mid-hills of Nepal, Roshan Subedi, Laxmi Dutt Bhatta, Erica Udas, Nand Kishor Agrawal, Keshab Datta Joshi & Dinesh Panday, *Cogent Food & Agriculture* (2019), 5: 1631026.

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