INTEGRATED STRAW MANAGEMENT IN NEPAL

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Foreword

The Development Papers Series of the Economic and Social Commission for Asia and the Pacific, Subregional Office for South and South-West Asia (ESCAP-SSWA) promotes and disseminates policy-relevant research on development challenges facing South and South-West Asia. The objective is to foster an informed debate on development policy challenges facing the subregion and sharing of development experiences and best practices.

This paper by Madhusudan Singh Basnyat is one of four national studies commissioned by ESCAP-SSWA and the Centre for Sustainable Agricultural Mechanization (CSAM) to better understand the status of crop residue management in South Asia. This paper examines the case of Nepal. The burning of crop residues is a major reason for severe air pollution in the Indo-Gangetic plain region. Crop residue or straw burning increases the concentration of particulate matter and black carbon in the air, adversely affecting the health of both rural and urban populations. This burning degrades soil fertility that needs to be compensated by greater use of fertilizers and can reduce agricultural productivity in the long run. Greenhouse gases emitted from burning also contribute to global warming and climate change. All of these factors adversely affect the achievement of the Sustainable Development Goals as crop residue burning harms our health and wellbeing (SDG 3), has implications on food security (SDG 2), affects the air quality of city inhabitants (SDG 11) and contributes to climate change (SDG 13).

It is hoped that the findings from this study highlighting issues faced by farmers in Nepal to sustainably manage crop residues is useful to identify opportunities to improve the existing situation as well as enable the policy makers to make relevant policy interventions. The study also collects good practices and technologies for managing straw (with particular emphasis on mechanization-based solutions) and proposes an action plan for interventions at the national level.

The findings from this study also contributes to a subregional report which summarizes the findings from the four national studies, explores key actions and the possibility of having a subregional framework for cooperation to promote sustainable and integrated management of straw residues.

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Integrated Straw Management in Nepal

Madhusudan Singh Basnyat [1]

Abstract

The burning of crop residue generates severe air pollution in the Indo-Gangetic plain area of South Asia. Crop residue burning affects people's health, degrades soil health that impacts agricultural production and food security and emits greenhouse gases contributing to climate change. Crop straw yield has kept growing and maintained a high level with increases in agriculture production in South Asia. The lack of suitable agricultural technology and machinery to sustainably utilize the straw or promote its recycled usage has led to straw burning, causing a high level of air pollution, including through transboundary sources.

This paper undertakes an analysis of the status of crop residue generation for three major crops (rice, maize and wheat), incidences of burning, factors that influences farmers' decisions to burn crop residue. The study finds that incidences of residue burning has increased particularly since the use of combine harvesters came into practice and that changes in livestock rearing practices through commercial rearing and use of alternative feed has also reduced demand for straw and market value of crop residues, particularly in the Terai region. Access to suitable techniques for integrated straw management is also lacking which leaves farmers with limited options for using crop residues. Various in-situ and ex-situ methods for managing crop residues as well as the agricultural machinery and equipment used in Nepal are documented.

The paper analyses various gaps and challenges that exist to ensure a more sustainable management of straw. Various recommendations are made on policy, research, mechanization and agriculture practice issues that can be considered to tap unrealized opportunities that alternative uses of crop residues can have to improve farmers' livelihoods and the environment. Some short, medium and long-term action plans, along with returning 75% of crop residue back to the field either by in-situ or ex-situ straw management are also proposed for the implementation of a "no-burn" campaign in Nepal.

JEL Codes(s): O13, Q16, Q53, Q55

Key words: crop residue management, straw burning, agriculture technology and machinery, air pollution

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1. Background

Straw is a valuable by-product of crop production as it is a natural resource that can be used for various purposes. In a traditional integrated crop–livestock farming system, crops were harvested manually using sickles, which left only short stalks with roots in the field. The harvested straw was used for livestock and household purposes, and there was no open burning. In recent years, there is an increasing trend in Crop Residue Open Burning (CROB). This paper studies the status of straw availability and its uses, causes of burning, remedies to stop burning and provide recommendations for the sustainable management of straw in Nepal.

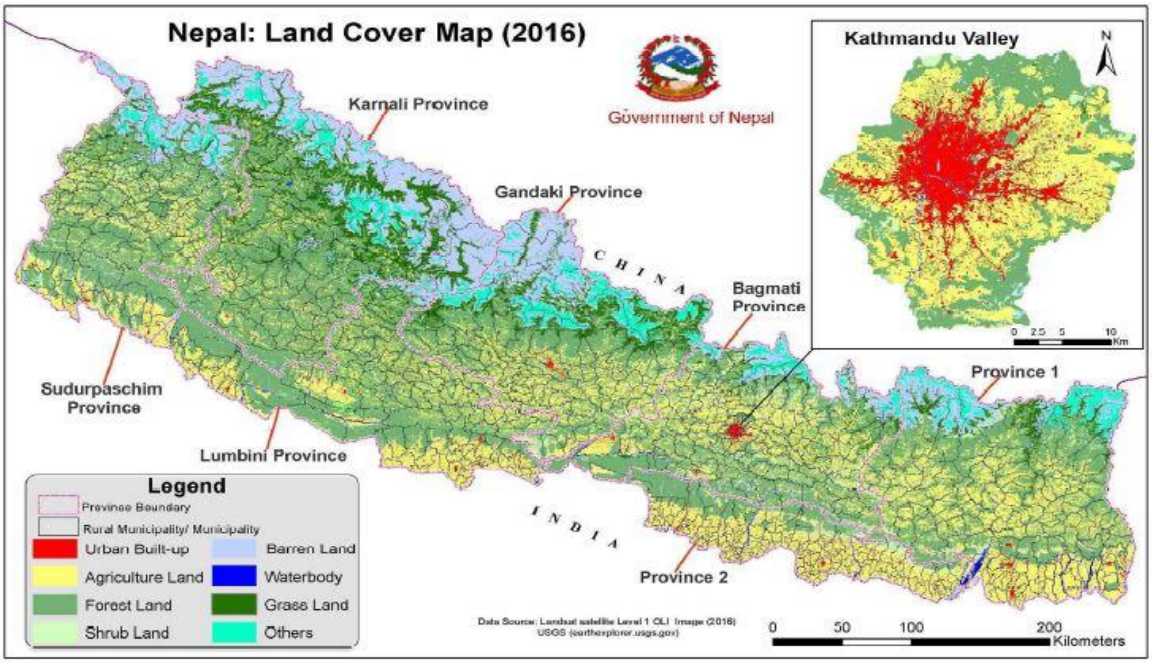
1.1 General

Nepal is a small, landlocked country in between India and China having an area of 147,181 sq. km. It is located on the southern slopes of the Himalayas, with Mountain, Hill, and Terai ecological zones (Figure 1). The Hill and Mountain regions cover 77% of the country and 23% by the Terai (plain area) region.

Figure 1: Physiographic regions map

Source: Ministry of Forests and Environment (2021)

Figure 2: Land use land cover map

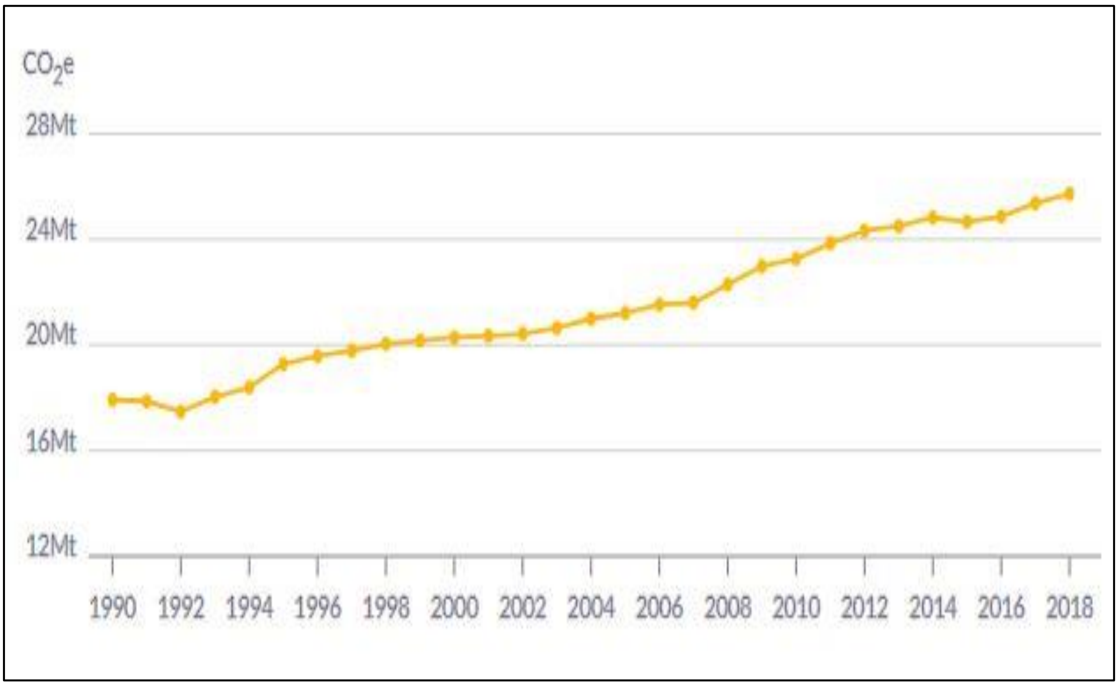


Source: Ministry of Forests and Environment (2021)

Nepal is an agricultural country with 60.4 % of the population engaged in agriculture. Only 28 % of the total land is cultivable (Figure 2). In 2019-20, agriculture (excluding livestock, forestry and fisheries) contributed 15.44 % to Gross Domestic Product (GDP) of which cereal and other crops was 8.49 %. Paddy and straw, maize and straw, and wheat and straw contributed 15.35 %, 8.85 %, and 6.34 %, respectively to total Agriculture GDP (AGDP) (MOALD, 2021).

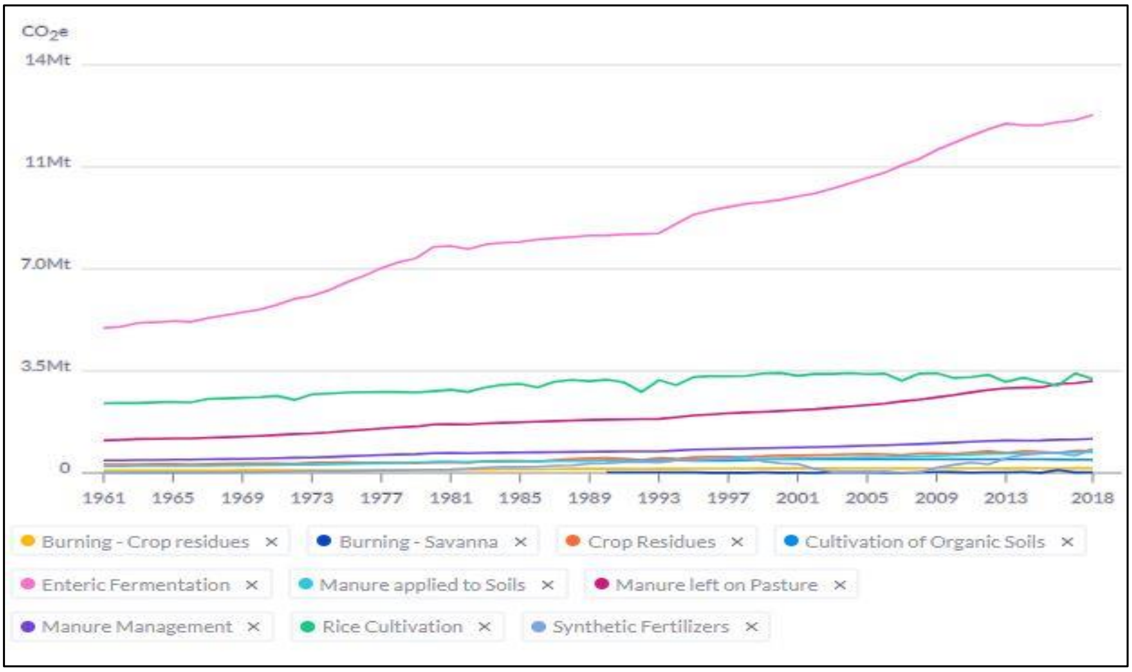
In 2013, greenhouse gas (GHG) emissions in Nepal were recorded as 40 Mt CO_2e, with agriculture contributing to 52 % of the total. The main sources of GHG emissions in the agriculture sector include enteric fermentation (around 55 %), rice cultivation (14 %), and manure left on pastures (13 %). Crop residue burning contributes to only 1% of agriculture sector GHG emissions (Annex 1) (CIAT, World Bank, CCAFS and LI-BIRD 2017). Historically, GHG emissions from agricultural sector increased in Nepal from 17.92 Mt CO_2e in 1990 to 25.79 Mt CO_2e in 2018 (Figure 3) (Climate watch, 2019a). Crop residue burning nearly doubled during a period of 57 years from 85 kt CO_2e in 1961 to 160 kt CO_2e in 2018 (Figure 4) (Climate watch, 2019b).

Figure 3: Historical agriculture sector for GHG emissions



Source: Climate watch (2019a)

Figure 4: Historical sub-sector in agriculture for GHG emission



Source: Climate watch (2019b)

1.2 Government Policies and Strategies

Until 2014, agricultural mechanization was not considered as essential for enhancing agricultural productivity in Nepal and was therefore not prioritized in national plans and programmes. For example, the *National Agriculture Policy-2004* did not consider agriculture mechanization as important (MOAD, 2004). However, the present chronic shortage of agricultural labour in many rural areas has brought agricultural mechanization to the policy agenda.

The *Agricultural Development Strategy (ADS) 2015-2035* is Nepal's overarching agricultural development plan for 20 years. It identifies agricultural mechanization as one of thirteen priority areas for achieving higher productivity and recognizes the role of the private sector in the mechanization of Nepal's agriculture. The strategy calls for mechanization by creating awareness, stimulating demand for machinery, concessionary financing arrangements and building the capacity of a nationwide network of machinery dealers, particularly for appropriate small-scale machineries like two-wheel power tillers and mini-tillers. It also calls for continuing the low levels of import taxes on agricultural machinery and exemption from value added tax (VAT) for selected machines.

While the ADS does not directly mention integrated straw management, the *Agricultural Mechanization Promotion Policy, 2014* (AMPP) indirectly refers to the management of crop residue (MOAD, 2014). It encourages the promotion of:

i) technology and machines appropriate for sustainable agriculture, minimum tillage and resource conservation;

ii) identification of energy and environmentally friendly machines;

iii) machines for organic fertilizer application;

iv) utilization of organic fertilizer, organic and bio-pesticides to achieve Integrated Pest Management (IPM), Integrated Nutrition Management (INM), Good Veterinary Practices (GVP), Good Livestock Practices (GLP), Good Agricultural Practices (GAP) and Good Fishery Practices (GFP).

In 2015, just after the AMPP came into action, some commercial livestock farmers of Rupandehi District in central Terai did not opt for the burning of leftover and standing stubble after harvesting paddy and wheat crops . Rupandehi is the first district where the highest number of Nepalese owned combines, and seasonally available Indian-owned combines are used on a custom hiring basis during the peak harvesting season. It was highlighted that if farmers deliberately set fire to the straw stubble of rice and wheat crops in the field, it destroys animal feed, soil structure and also causes adverse environmental impacts. Hence, the Government of Nepal (GON) approved and enforced a law by publishing a notice in the Gazette of Nepal on 20 April 2015 (07 Baishak 2072) mentioning that combine harvesters without straw collecting machines such as straw reapers and/or balers, etc., are not allowed to be imported or used for custom hiring businesses. This was a positive decision for straw management in the country (Annex 2).

2. Rationale and objective of the study

The Centre for Sustainable Agricultural Mechanization (CSAM) of ESCAP organized the Fourth Regional Forum on Sustainable Agricultural Mechanization in Asia and the Pacific in Hanoi, Vietnam in 2016. The Forum emphasized the need for strengthening and promoting climate-smart agriculture and agricultural mechanization through Integrated Straw Management in Asia-Pacific. As a follow-up, a study was undertaken by a team of experts to find out the status of straw management in East, South, and Southeast Asia which was presented to stakeholders at the Fifth Regional Forum held in Kathmandu, Nepal in 2017. Experts from the International Maize and Wheat Improvement Center (CIMMYT) and the International Rice Research Institute (IRRI) also shared their perspective at the Forum. Subsequently, CSAM initiated pilot projects on integrated straw management in China and Vietnam, and the initiative is now being expanded to other countries like Cambodia, Indonesia and Nepal.

Furthermore, CSAM in collaboration with ESCAP's Subregional Office for South and South-West Asia (ESCAP-SSWA) is advancing sub-regional cooperation for sustainable, climate-smart and integrated management of straw residue. To support this, a team of experts has been engaged to conduct research to understand the status of straw management in Bangladesh, India, Nepal and Pakistan. The objectives of this Nepal specific study on the status of straw management are to:

- Identify existing mechanisms and practices of straw residue management, as well as support being provided by the Government
- Identify existing gaps in knowledge and technology/machinery for using the straw waste for more purposeful uses
- Recommend actions at the national level.

3. Status of straw resources

Crop production results in more than equal quantity of by-products like straw, husk, brans etc. Rice is the main staple food grain crop, followed by maize and wheat in terms of area and production. The other crops grown are oilseeds, legumes, cash crops, but the quantity produced is less than paddy, maize or wheat, and straw production from these crops is also low.

The Mountain region (3,000 m above mean sea level) is where most of the barren land is found and has less scope for agricultural land use intensification, mainly due to rugged topography and climatic conditions. The main paddy growing areas of Nepal are in the plain land of Terai districts, inner valleys and river basins where irrigation is available. Rainfed paddy cultivation can be found all over climatically suitable areas during the monsoon or rainy season. Wheat is generally followed after paddy in the Terai, about 57% of wheat production area lies in Terai. The Mountain, Hill, and Terai regions contribute 3%, 26%, and 71% of the total paddy production area, respectively. The Hill region contributes to 74% of the total maize production area. Maize is the first staple food of rural households in the Hill region, followed by paddy cultivated under irrigated or rainfed conditions (Table 1).

Table 1: Area under major cereal crops production by ecological region during 2016-17

Ecological belt	Paddy, ha (%)	Maize, ha (%)	Wheat, ha (%)
Mountain	55 (3)	88 (10)	53 (7)
Hill	399 (26)	664 (74)	264 (36)
Terai	1,094 (71)	147 (16)	418 (57)
Total	**1,549 (100)**	**900 (100)**	**735 (100)**

Source: Timilsina et al. (2019)

The average grain and straw production of three main cereal crops, and the value of straw are calculated for three fiscal years (Table 2). The straw grain conversion factors depend on crop variety, agro-ecological differences, method of harvesting and processing, and the method of data collection, etc. The straw grain ratio and value of straw are calculated based on the publication "Cost of Production and Marketing Margin of Cereals, Vegetables and Industrial Crops 2074-75 (2017-18)" by Agribusiness Promotion and Market Development Directorate, Market Research and Statistics of Department of Agriculture (Annexes 3-8).

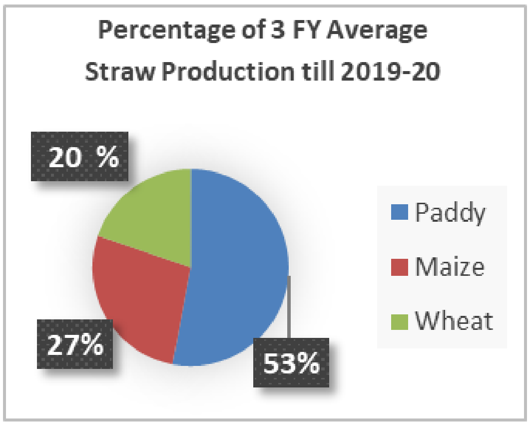
Table 2: Grain production, straw grain ratio, straw value and straw production of major crops

Crop	Grain Production ('000 Mt)*			Average Grain Prod. ('000 Mt)	Straw-Grain ratio**	Straw Prod. ('000 Mt)**	Straw Price (NPR/Mt)	Avg. Value of Straw ('000 NPR)***
	2017-18	2018-19	2019-20					
Paddy	5,151	5,610	5,551	5,437	1.10	5,981	1,397	8,355,457
Maize	2,555	2,713	2,835	2,701	1.14	3,079	558	1,718,082
Wheat	1,949	2,005	2,185	2,046	1.09	2,231	1,402	3,127,862
Total				**10,185**		**11,291**		**13,201,401**

*Source: *MOALD (2018, 2019a, 2020)*
*Note: **Department of Agriculture (2018), Cost of Production and Marketing Margin of Cereals, Vegetables and Industrial Crops 2017-18 (Annexes 3-8)*
**** 1 USD=122.25 as on April 29, 2022*

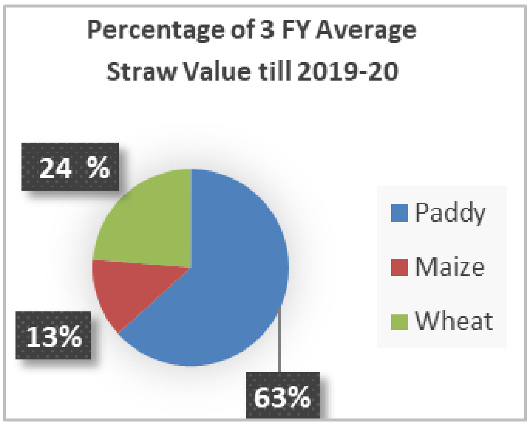
The percentage straw production and its value for three major crops during 2017-18 to 2019-20 are reported in Figures 5 and 6.

Figure 5: Straw production



Source: Calculated from Table 2 data

Figure 6: Straw value



Source: Calculated from Table 2 data

The distribution of crop straw depends upon the agro-ecological region. The area under paddy and wheat cultivation is the highest in the Terai region (Table 1) and this is where straw as a by-product is mostly produced. The dried maize stalks are generally used for burning as fuel for cooking food for humans or livestock. Green stalks are used for livestock feed in Hill and Mountain regions, but are in deficit during the lean season. The lack of alternate uses of surplus straw has resulted in open air burning in the Terai region, whereas deficits exist in the Hill and Mountain areas. Hence, livestock farmers of Hill and Mountain regions are transporting loose bulk rice straw from the Terai to stock for lean season (Figure 7).

Figure 7: Transporting loose bulk straw from the Terai to Hill and Mountain districts for stocking for the lean season

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4. Status of Straw Burning in Nepal

Rural households use straw as base material for making cow dung cakes for cooking fuel, for feed and livestock bedding materials, mulching, burying and re-ploughing in the field, making straw mattresses, roofing/thatching, space heating during winter, etc. The volume of straw production keeps on increasing with increases in food production. However, the use of new forms of modern feed materials for commercial livestock farms have reduced the use of crop residue.

As mentioned above, multiple crop residue management techniques are used by the individual farmers depending upon their needs. The efficient utilization of crop straw is hindered by many factors such as

- Costlier collection;
- Changes in livestock rearing;
- Alternate cooking fuel; and
- Access to suitable techniques of integrated straw management (ISM).

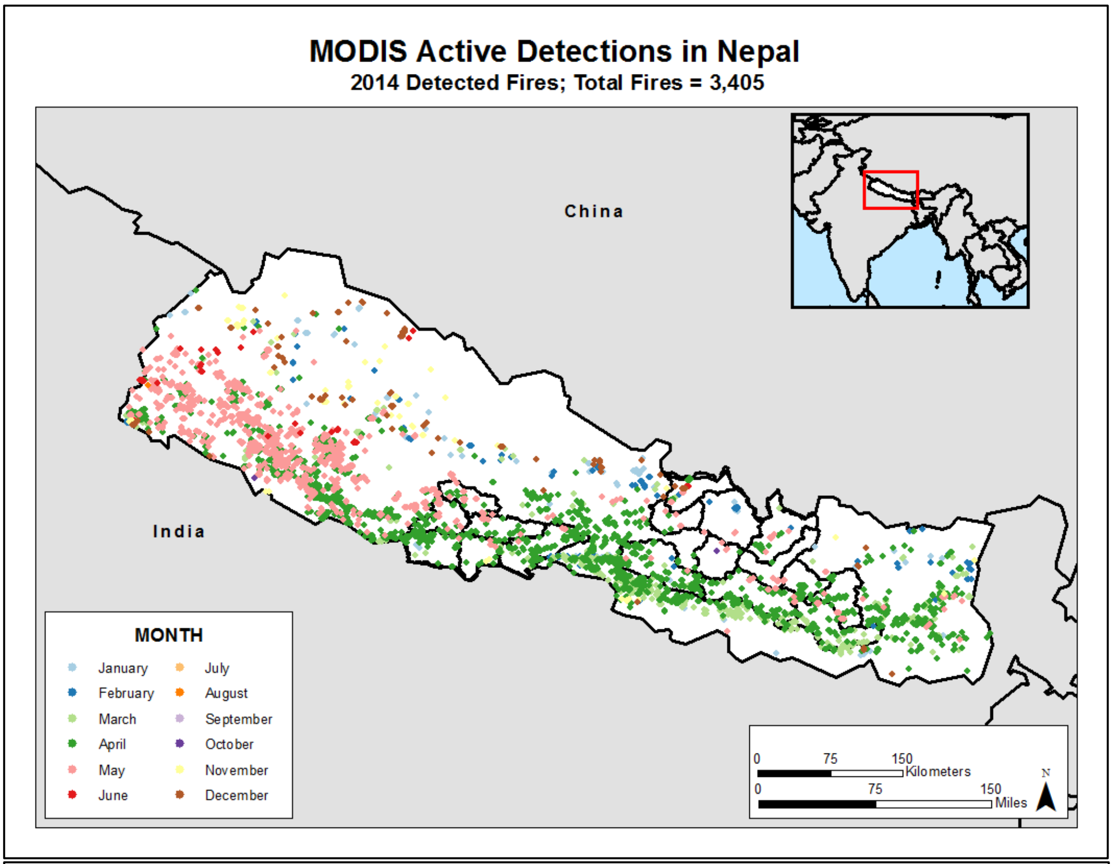
Hence, if straw is not utilized, the easy way out is open burning of crop residues in the fields.

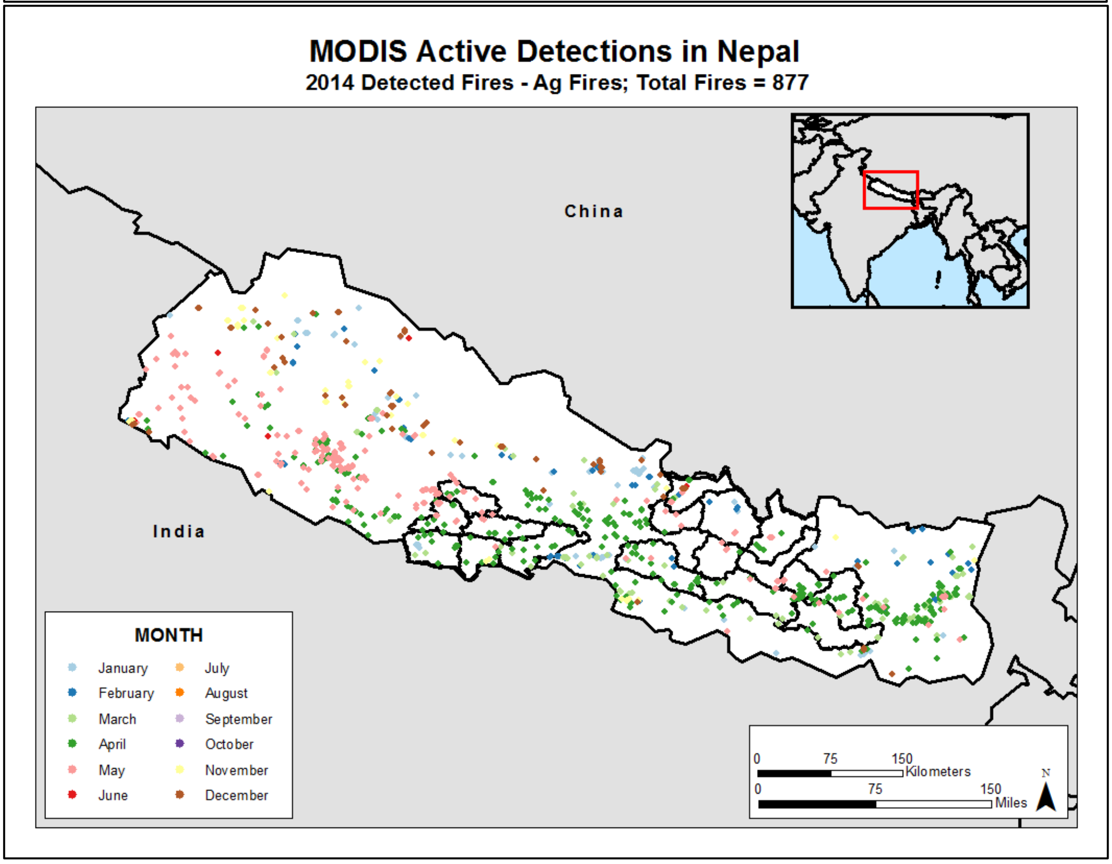
Statistical figures on the amounts of straw burned in terms of severity and location are lacking and not readily available from single official sources. Research conducted by Das et al. (2020) indicated that open burning of crop residue varies according to the geographical region of the country. For the year 2016-17, the highest residue burning occurred in the Terai region (90.7 %), followed by the Hill (6.4 %) and the Mountain (2.9 %) regions. This could be due to various factors. The Terai region has higher agricultural production than the other two regions. Therefore, 66.8 % of residue generation are due to the accessible land-use area of the Terai, followed by the Hill (27.7 %) and the Mountain (5.5 %) regions. In addition, both the supply and demand for dry fodder consumption determined the level of crop residue burning. In districts where there are feed deficits, i.e., the mountain and hills, open burning was low or non-existent. Likewise, in districts where there was feed surplus, open burning was high.

4.1 Agricultural Fire Incidents

Agricultural fires are one of the sources of GHG emissions, although its contribution to Nepal's total GHG emissions is only 1 %. However, Paudel et al. (2017) have noted that agricultural fires are increasing at an alarming rate due to rapid spread of use of combine harvesters (CH). Paudel et al. (2017) presented that the increase in fire incidents on agricultural land, i.e., potential crop residue open burning, are being detected through remote sensing. The images captured by MODIS: Moderate Resolution Imaging Spectroradiometer in 2014 detected 877 agricultural fires out of a total of 3,405 fires (Figure 8). Similarly, VIIRS: Visible Infrared Imaging Radiometer Suite in 2016 detected 9,908 agricultural fires out of a total of 61,725 fires (Figure 9). The following images clearly shows that the agriculture fires are on an increasing trend.

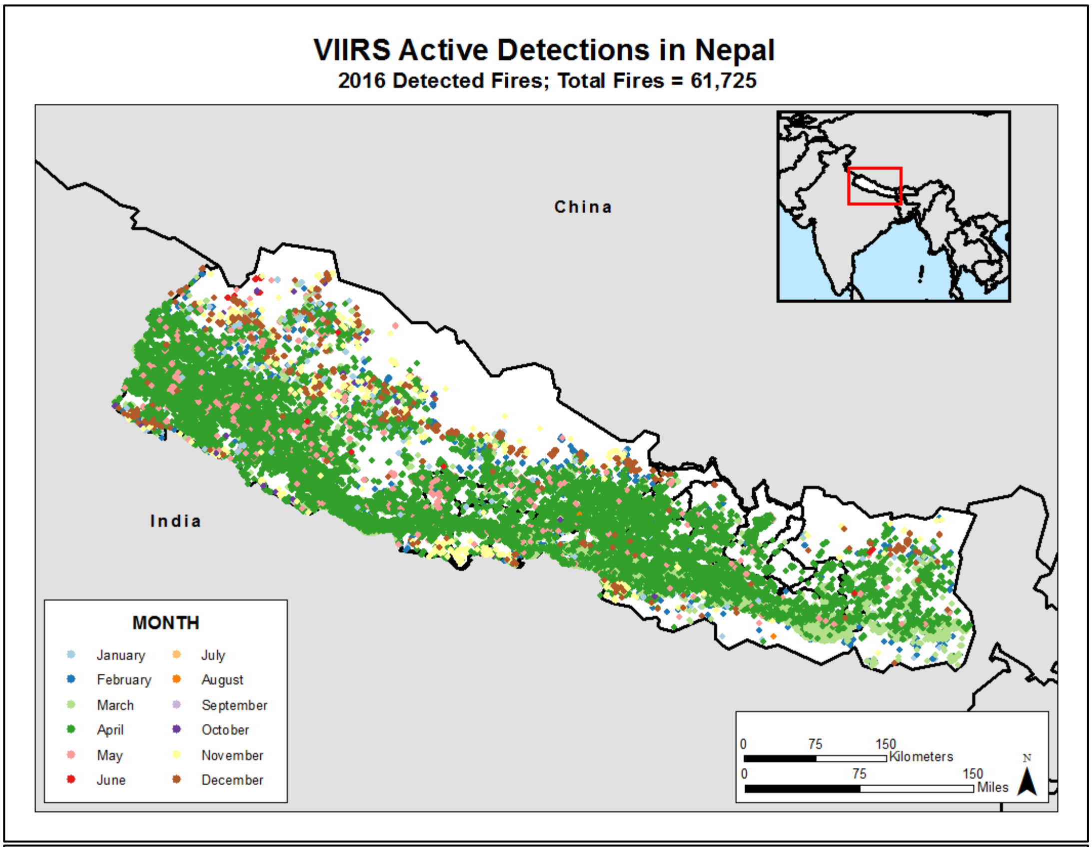
Figure 8: MODIS: Moderate Resolution Imaging Spectroradiometer detected active fires in year 2014

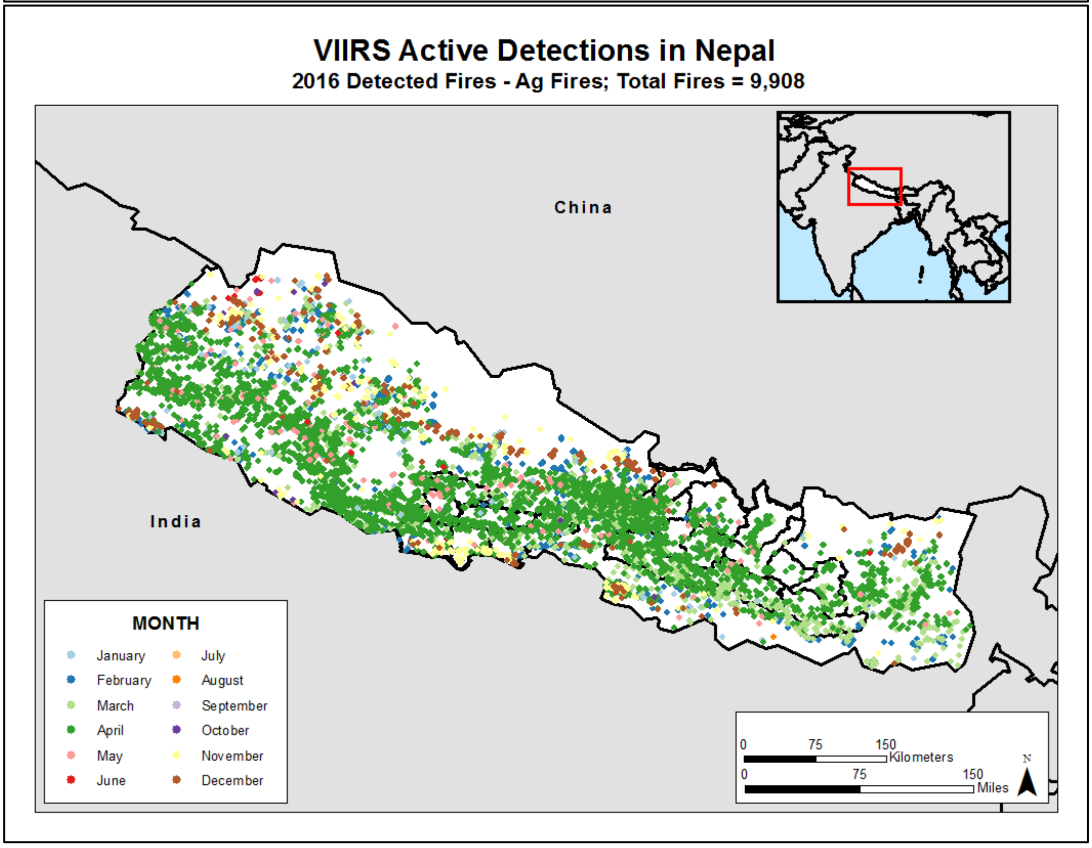




Source: Paudel et al. (2017)

Figure 9: VIIRS: Visible Infrared Imaging Radiometer Suite detected active fires in year 2016



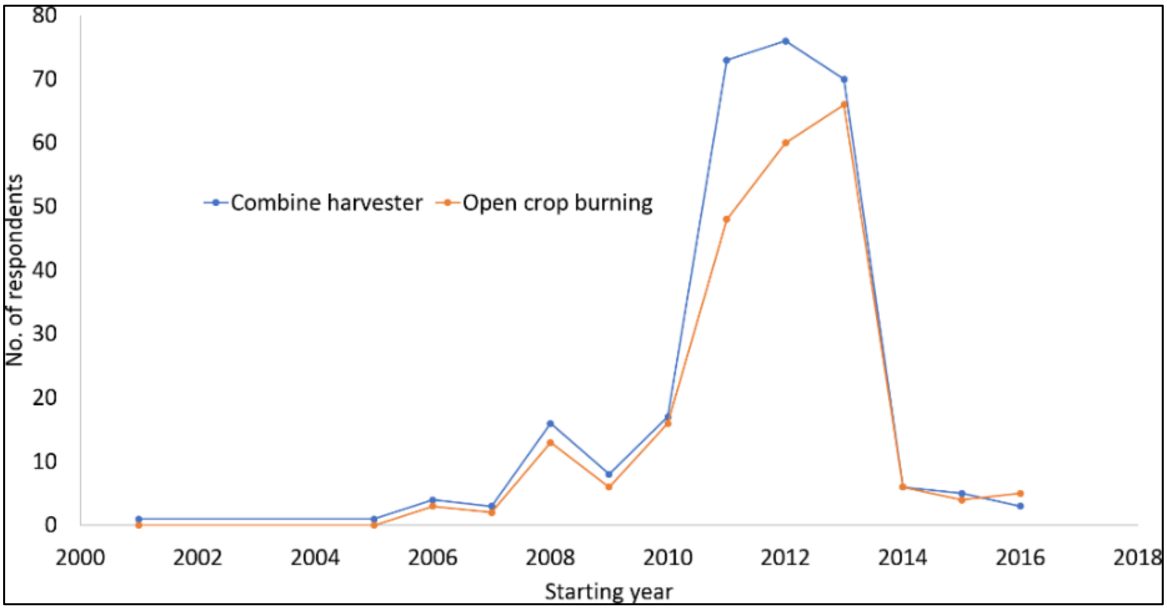


Source: Paudel et al. (2017)

4.2 Determining Factors for Crop Residue Open Burning (CROB)

The first combine harvester (CH) in Nepal was purchased and registered by Mr. Ananta Kadel from Butwal, Rupendehi district in the year 2000. Before that combine harvesters were brought to Nepal by seasonal Indian custom hiring service providers. The use of combine harvesters is now rapidly increasing in other parts of Nepal. Bajracharya et al. (2021) conducted a study in 2016 to understand the determining factors for CROB in three Terai districts of Kapilvastu, Nawalparasi and Rupandehi which the Indian state of Bihar in the south and are part of the upper Gangetic Basin. The selected districts have most of the users of CH in the country. The farmers were selected from one municipality and two village development committees (VDCs) in each of three districts. It was observed that over 80% of farmers in Rupandehi and Kapilvastu and 68% of farmers in Nawalparasi use combine harvesters. A preliminary field visit revealed that these districts were major open crop residue burning areas due to difficulty in retrieving residue scattered across the fields after the use of a combine harvester.

Figure 10: Trends in the start of combine harvester use and open residue burning



Source: Bajracharya et al. (2021)

The choice of harvesting method and the choice of residue burning are two interdependent decisions. The major factors influencing decisions to burn crop residue are listed below:

- Plots using **combine harvesters** were found to be 54% more likely to have their crop residue burned as compared to plots in which manual labour was deployed. The increasing trend in the use of combine harvesters overlaps with the increasing trend in open residue burning (Figure 10).
- **Livestock ownership** was another major driver in the farmer's choice of a method of harvesting. It was observed that farmers owning livestock were 26% less likely to use combine harvesters.

- Farmers having **non-farm employment** were 8% more likely to burn crop residue than farmers whose main source of income was from agriculture.
- Farmers **aware** of the negative effects of burning the residue were 7% less likely to do so.
- With a **higher household size** of the farmer, they were 1.3% less likely to burn residue.

The study conducted by Paudel et al. (2015b) in the same three Terai districts (Nawalparasi, Rupendehi and Kapilbastu) in the year 2014 indicated that the area of coverage per year by a combine harvester was not increasing significantly and may have been due to competition among the service providers. The percentage coverage of rice and wheat harvesting by combine harvesters was 8% and 21%, respectively in 2014 (Table 3).

Table 3. Total coverage of rice and wheat area by combine harvesters (CH) in selected districts

Year	*Total no of CH*	*Rice area (%)*	*Rice area (ha)*	*Wheat area (%)*	*Wheat area (ha)*	*Avg. area covered by each CH (ha/yr)*
2000	1	0.14	250	0.35	252	500
2001	3	0.42	750	1.05	756	500
2004	*5*	*0.71*	*1250*	*1.75*	*1260*	*500*
2007	6	0.85	1500	2.10	1512	500
2009	*9*	*1.28*	*2250*	*3.16*	*2278*	*500*
2010	24	3.07	5400	7.58	5445	450
2011	*36*	*3.58*	*6300*	*8.84*	*6353*	*350*
2012	88	5.63	9900	13.90	9983	225
2013	*134*	*7.62*	*13400*	*18.82*	*13512*	*200*
2014	150	8.53	15000	21.07	15126	188

Source: Paudel et al. (2015b)

The major reasons behind crop residue open burning in this study were due to a lower preference of ruminants in feeding on combine harvested straw, the labour-intensive process for collecting crop residue, lower stocking size and lower market value of the crop residue (Table 4).

Table 4: Reasons for crop residue burning

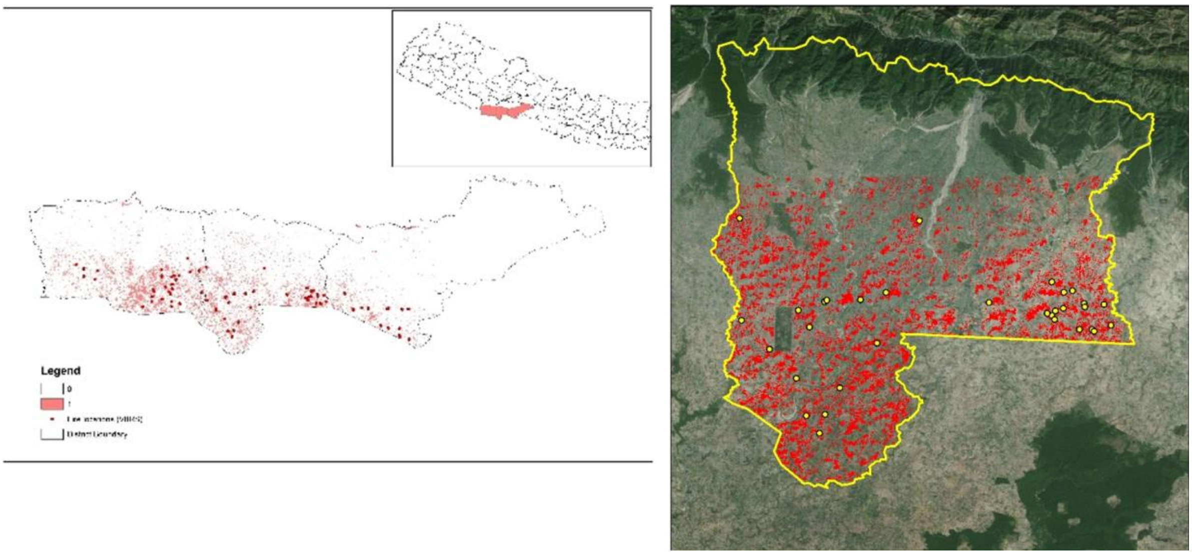
Reasons	Rice (n=78)	Wheat (n=75)
Animals do not prefer CH used straw	25 (32)	20 (27)
Labour intensive process for collecting crop residue	12 (15)	9 (12)
Lower stock size	20 (25)	26 (35)
Lower market value for crop residue	21 (27)	20 (26)

Source: Paudel et al. (2015b)
Note: Figures in parenthesis indicates the percentage

4.3 Combine Harvester (CH) major determinant for CROB

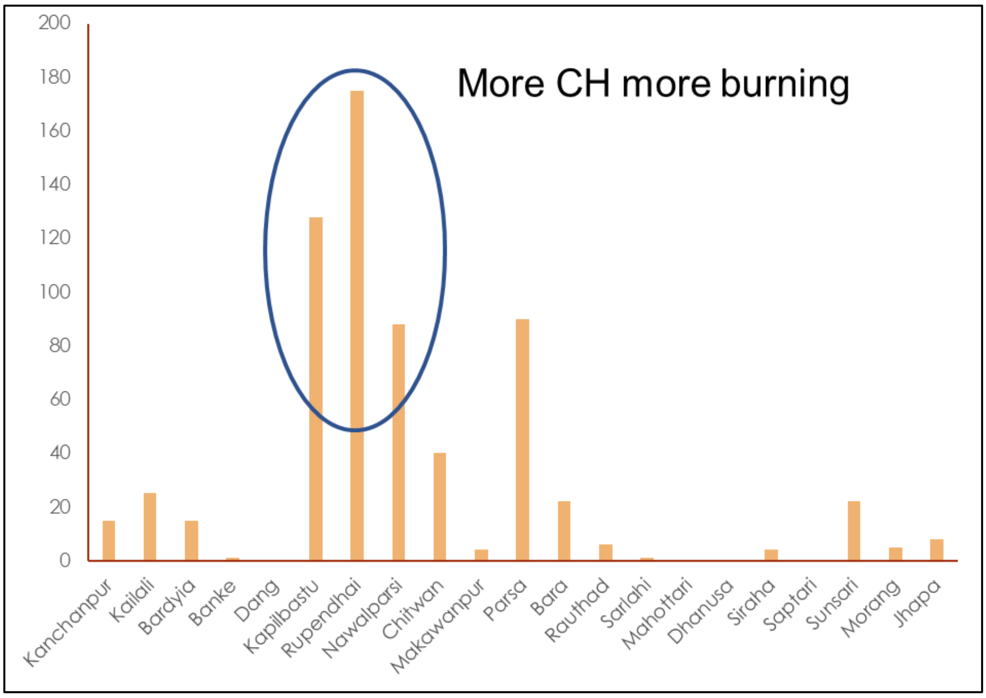
The main determinant for increase in CROB is widespread use of combine harvesters. CH leaves long stubble and un-scattered straw on the field, making manual collection difficult and requires a special straw collecting machine attached to a tractor. Therefore, an easy option is to burn straw in the field. Figure 11 shows that the burning areas of the Rupendehi and its adjoining districts matched with the operation of a greater number of CH in Kapilbastu, Rupendehi and Nawalparasi districts (Figure 12). This clearly indicates that the open burning of crop residue is directly related to the number of CH in operation.

Figure 11: Burning areas of the Rupendehi and its adjoining districts



Source: Paudel et al. (2017)

Figure 12: Number of combine harvesters (CH) in Terai in 2016



Source: Paudel et al. (2017)

Bajracharya et al. (2021) conducted a study on the determinants of crop reside burning in three districts of Kapilvastu, Nawalparasi and Rupandehi of Nepal in 2016. The analysis showed that the prevalence of CROB was correlated with the increasing trend of CH use (Figure 10).

4.4 Nutrient loss due to CROB

Despite a saving of US$ 88 per ha from rice and US$ 116 per ha from wheat after using CH as compared to manual harvesting, intense residue burning has exacerbated nutrient losses of over 35,000 Mt of carbon, 561 Mt of Nitrogen, 40 Mt of Phosphorus, 254 Mt of Potash and 38 Mt of Sulfur from the selected three districts of Kapilvastu, Nawalparasi, and Rupandehi in 2013-14 (Table 5) (Paudel et al., 2015b).

Table 5: Nutrient loss from rice and wheat straw burning in the study area

Nutrient	Rice				Wheat				Total nutrient loss in study districts (Mt)
	Conc. in straw (kg/Mt)	Loss in burn (%)	Loss (kg/ha)	Total loss (Mt)	Conc. in straw (kg/Mt)	Loss in burn (%)	Loss (kg/ha)	Total loss (Mt)	
C	400	100	1480	22,206	400	100	1067	12,913	35,119
N	7.0	90	23.3	349	7.3	90	17.5	212	561
P	2.3	25	2.1	31	1.1	25	0.7	8.9	40
K	17.5	20	12.9	194	9.4	20	5.0	60	254
S	0.75	60	1.6	24	0.75	60	1.2	14	38

Source: Paudel et al. (2015b)

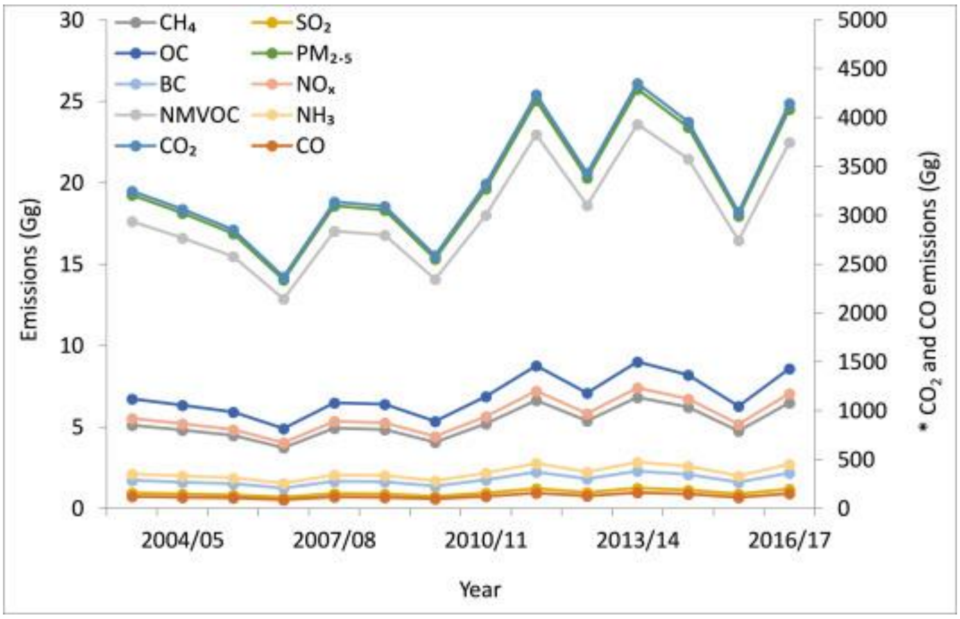
Note: The data were calculated based on the areas under rice (~15,000 ha) and wheat (~15,126 ha) crops and coverage of CH. The nutrient composition of rice straw and percent loss in burning was calculated as per Dobermann and Fairhurst (2002) and wheat straw and percent loss was calculated as per Tarkalson et al. (2009). The productivity of rice and wheat straws was assumed to be same with sample data for the entire areas.

4.5 Pollution due to CROB

The burning of crop residue is one of the most significant sources of pollution in the Indo Gangetic Plain (IGP) during the rice harvesting season (October–November) and wheat harvesting season (April–May) (Bajracharya et al., 2021). The burning of biomass releases a range of air pollutants that contribute to the deterioration of air quality as well as greenhouse gases that affect the climate in the longer term, including carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and fine particles known as black carbon (BC). The harmful effects of biomass burning range from adverse human health and diminished crop growth to the degradation of natural ecosystems and physical infrastructure.

National air pollutant emissions from 2004-05 to 2016-17 showed an increasing trend (Figure 13) (Das et al., 2020). It was observed that emissions were the highest in 2013-14 and the lowest in 2006-07. A significant drop in air pollutants was seen in 2015-16, which could be due to the lack of production caused by the severe earthquake that occurred in Nepal in April 2015. The regular agricultural practices of people were seriously disrupted by the extensive damage suffered during this emergency, in turn reducing Crop Residue Open Burning (CROB).

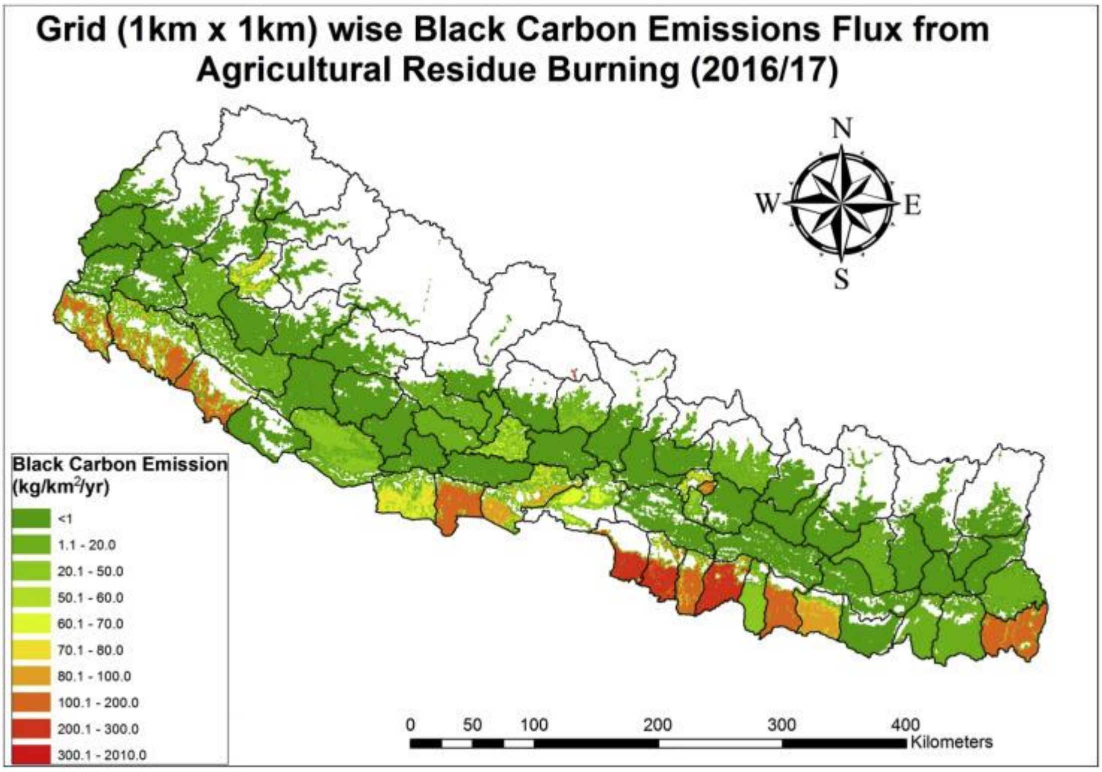
Figure 13: National trends in emissions from crop residue open burning (2003–2017)



Source: Das et al., 2020

The same study reports the district-wise black carbon emissions (Grid 1 × 1 km) for the entire country under cultivated areas at the district level. It shows that while black carbon emissions were widespread and high in the Terai region, it was the lowest in the mountains and hills (Figure 14). Black carbon is a high priority pollutant in Nepal and the Hindu Kush Himalayan region. It is the second most anthropogenic climate-force at present after carbon dioxide and is triggered by incomplete combustion.

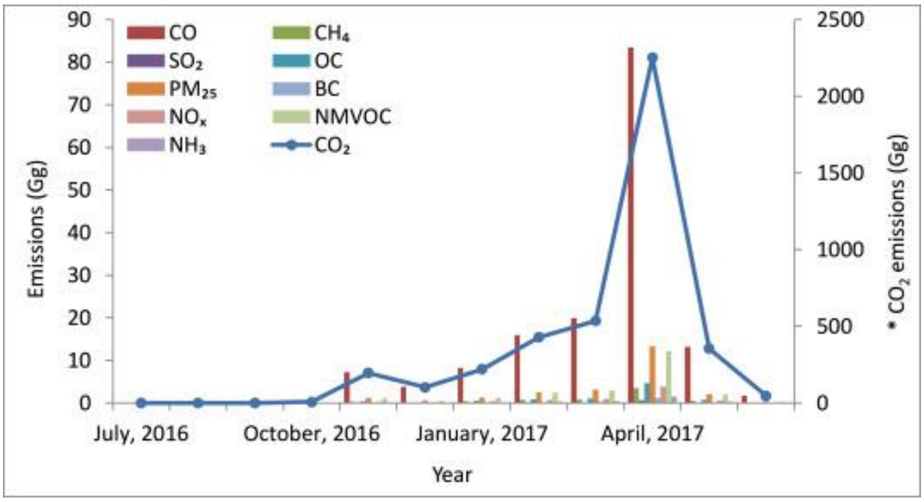
Figure 14: Black Carbon emission flux from agricultural residue burning in 2016-17



e: Das et al., 2020

The active fire counts were combined for the calculation of the temporal variations in emissions (Das et al., 2020). It was highly concentrated from February to May (86.16 % of the total emissions), with the peak in April (Figure 15). The open burning of crop residue of winter crops during this time could be the reason for high air pollutants. However, with the onset of the regular monsoon rains in Nepal, the agricultural residue open burning practices decline or do not occur in sizes and volumes that can be detected by a satellite. Therefore, emissions were estimated to be zero during this season.

Figure 15: Monthly variation of emissions (2016-17)



Source: Das et al., 2020

4.6 Availability and Utilization of Combine Harvesters

In 2019, the Ministry of Agriculture and Livestock Development (MOALD), along with the Nepal Agriculture Research Council (NARC) and CIMMYT, conducted a study in six Terai districts, including Bara and Parsa from Province 2 (Madesh Pradesh), Nawalparasi and Rupandehi from Province 5 (Lumbini Pradesh) and Kailali and Kanchapur from Sudur Paschim Province on the utilization and availability of combine harvesters. There are about 750 combine harvesters (CH) in operation in the country. About 20% of CH come from India during the peak rice and wheat harvesting periods. The study found that the use of CH helps in harvesting faster (0.6 ha/h) and results in labour saving (50%) and cheaper than manual harvesting (Table 6). Generally, a CH harvests a maximum of up to 204 ha of rice (average 98 ha) and 238 ha of wheat (average 120 ha) in one crop season in the study cluster (Table 7). The rental charges for harvesting rice/wheat by CH are reported in Table 8. The Indian CH service provider also pay a custom tax of NPR 1,700 per day.

Table 6: Cost comparison and saving with CH against manual harvesting per ha

Crop harvested	Manual by Sickle and threshing by thresher /winnowing (NPR)	Combine Harvester (NPR)	Cost Saving by CH (%)
Rice	14,490	7,247	50
Wheat	14,490	7,667	47
Average	**14,490**	**7,457**	**48.5**

Source: MOALD (2019b)

Table 7: Rice and wheat area harvested by each CH

District/Cluster	Harvested area range (ha)		Harvested average area (ha)	
	Rice Season	Wheat Season	Rice Season	Wheat Season
Bara and Parsa	82-102	102-136	95	114
Rupandehi and Nawalparasi	68-204	68-170	119	105
Kailali and Kanchanpur	41-136	41-238	80	141
Range/Average	**41-204**	**41-238**	**98**	**120**

Source: MOALD (2019b)

Table 8: Rental charge for harvesting rice/wheat (NPR per ha)

District/Cluster	Range	Average
Bara and Parsa	3400-4080	3854
Rupandehi and Nawalparasi	3060-3400	3196
Kailali and Kanchanpur	2720-3400	3315
Range/Average	**2720-4080**	**3455**

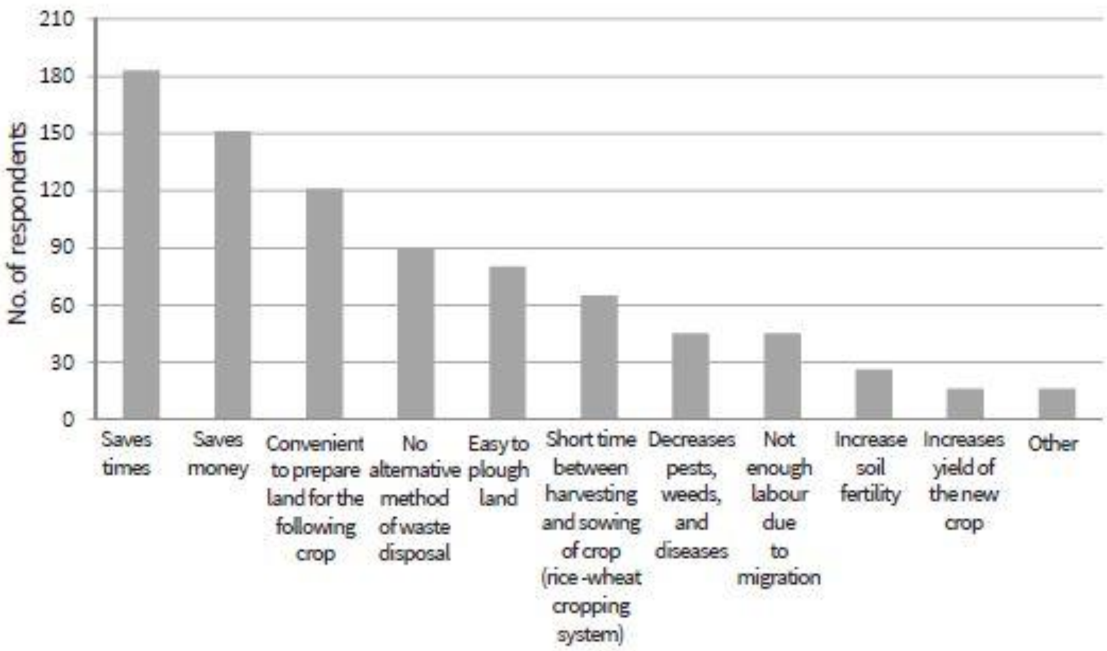
Source: MOALD (2019b)

The rental charge for combine harvesters is mostly on an area basis; only in some places, it is on a time basis. For the six districts in the MOALD study, rental charges were on an area basis, so quicker harvesting of an area would generate more rental earnings per unit time. Therefore, operators cut the crop as high as possible in order to cover an area quickly and left long stubble in the field. Operators are also paid an additional bonus for the volume of the harvested crop. Under the time basis modality, operators cut the crop as low as possible in order to spend more time in harvesting an area and there is thus no issue of long stubble being left in the field. Collecting long stubble is a difficult task which needs additional effort, investment, and specialized machines. Therefore, an easy way to overcome this problem of open burning in the field is to change the rental charge from an area to a time basis.

4.7 Women farmers' perceptions of CROB

An ICIMOD study conducted in 2018 in three Terai districts in Nepal (Nawalparasi, Rupandehi, and Kapilvastu) reported that women farmers were aware that crop residue burning harms the health of their families, the environment and air pollution during the process, and also results in loss of the soil productivity in the long run. However, the practice of crop residue burning still continues in studied districts due to time and money savings, greater convenience, lack of alternative straw disposal methods, etc. (Figure 16).

Figure 16: Women farmers' perceptions for reasons for burning straw



Source: ICIMOD (2020)

5. Straw management pattern

Crop residues of 11 million tonnes having a value of NPR 13 billion are produced from three major crops in the country every year. Straw is a valuable biological by-product of crops that can be used to better the farming community. There is a need to stop the burning of such a natural gift of nature to improve the agricultural ecological environment. Straw can be used as fertilizer, base materials for mushroom production, bedding materials for livestock, raw materials for paper, raw material for production of ethanol, briquettes, bio-gas fuel, gasification fuel, carbonization fuel, fodder, incorporated into soils and used as mulching materials. However, such uses of straw are limited in Nepal. The in-situ and ex-situ management practices found in Nepal are described in the next sections.

5.1 In-situ Straw management

In-situ straw management technique refers to the management of leftover straw without removing it from the field. Various agricultural machines can be used to manage straw in this technique, however, new innovative energy efficient machines need to be put in practice. Some of the technology in practice are discussed below:

Straw used as fertilizer by direct retuning to the soil: In this technique, the straw is either chopped and mulched and seeding is done simultaneously or chopped and incorporated into the soil using a rotavator or disc plough. This reduces the burden of collecting and carrying away straw from the field. The straw will start decomposing in due course of time, releasing nutrients and improving the soil organic matter. This technique can be sub-divided into two types.

(a) Soil cover with straw: In this technique leftover straws or standing stubble are chopped, and seeding of succeeding crop is done using suitable agricultural machines.

Figure 17: Happy Seeder

©S. Shakya

Happy seeder is a no-till seed drill which chops the long-standing stubble of 40-50 cm and straw into small pieces and covers the soil while simultaneously sowing seeds and fertilizer in row. Happy seeders require more powerful 4WD tractors, although there are now eco-seeders that are available in the market, which can be operated by low horsepower tractors. Around 40 Happy seeders are being used in the far-west, mid-west, central parts of Nepal by commercial farmers and in research stations. Happy seeders are not commonly used among the marginal farmers as the capital investment is high. The Agricultural Implement Research Station (AIRS), Birgunj of NARC has reported a field capacity of 0.3 ha/hr, fuel consumption of 4 litres/hr and crop yield 4.1 tonnes/ha for NL971 variety wheat sowing by a Turbo Happy Seeder (NARC, 2021; NARC, 2022). The testing and evaluation of the performance was conducted on station and on farm at different locations of Parsa district. A promotional leaflet on the Turbo Happy Seeder has also been developed to disseminate the technology among the farmers to stop open burning of crop straw residue. (Annex 9)

Figure 18: Zero-till seed cum fertilizer drill

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Zero-till seed cum fertilizer drill does not chop straw, but sow seeds and fertilizers directly into the soil without ploughing. It is good for a standing short stubble field and requires less powerful 4WD tractors than Happy seeders. More than 100 such machines are in operation. These machines are popular in far-west and mid-west regions as compared to eastern parts of the country.

(b) Straw incorporated into soil: In this technique, standing stubble is chopped into pieces and incorporated into the soil which decomposes in due course of time.

Figure 19: Power tiller driven roto till seed cum fertilizer drill

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Roto till Seed cum fertilizer drills are driven by a power tiller. It is commonly known as *minimum tillage* that is cheap and the best suited Resource Conservation Technology (RCT) for marginal farmers. The straw is chopped into small pieces with an S-type rotary tiller blade and incorporated into the soil. Seeds with fertilizers are simultaneously sown in a row, followed by a roller covering the seed. This type of minimum tillage is very common among the smallholder farmers of far-west and mid-west, but not popular in the eastern parts of the country. It is estimated that around 1000 units are in operation.

Figure 20: Super Seeder

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Super seeders and eco-seeders are a new innovation with very few in country. The working principle is the same as a power tiller driven seed cum fertilizer drill, but it is driven by less powered 4WD tractors than required for Happy seeders. Under the pilot project of CSAM, one super seeder was purchased, and training for operators and demonstration to farmers of Mechi, Koshi and Sunsari had been conducted.

Figure 21: Rotary mulcher

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Rotary mulchers cut standing stubble and leftover straws into small pieces and lay them over the surface of the field. Rotavators, cultivators, disc ploughs, mould-board ploughs, etc., are then used to incorporate straw into the soil. If a rotary mulcher or chopper is not available, then the field is ploughed directly using traditional methods to incorporate these uncut straws into the soil. This is followed by the broadcasting of seeds and fertilizers with slight ploughing. The Agricultural Implement Research Station (AIRS), Birganj of NARC has reported field capacity of rotary mulchers as

0.65 ha/hr and 0.42 ha/hr at high and low speed respectively. It was observed that the mulcher operated smooth in dry soil compared to wet soil (NARC, 2021; NARC, 2022). The testing and evaluation of the performance was conducted at the AIRS.

Direct ploughing is a very common practice where tractors and rotavators are easily accessible by the farming community. Otherwise, burning of straw and traditional ploughing practice is common where these machines are unavailable.

Figure: 22: Rotavator

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5.2 Ex-situ Straw management

Ex-situ straw management refers to techniques of processing crop straw into different forms, adding value and using it for several purposes after collection from the field, either manually or by using different machines like straw reapers, balers, etc. The use of such management techniques is limited in the country.

Straw Collecting Machines: Hand collection of straw left on the field is a tedious but important job for ex-situ management. To ease this task, there are various types of tractor-operated or self-propelled straw collecting machines are available. The brief details of some of these used in the country are as follows.

Straw/hay baling is a straw collecting technique. Bales of different sizes and shapes can be stored for later use as feed in the lean season or for any other alternate use. Affordability and availability of baler machines of different sizes are limited, even though there is a restriction on the import of combine harvesters without it. In some parts of the country, baling machines are being

Figure 23: Baler

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used to harvest paddy and wheat straw, which facilitates the transport and storage of bulky straw in small spaces. The Agricultural Implement Research Station (AIRS), Birgunj of NARC has reported an average time of 2.08 minutes/bale that is around 30-35 bales/hour in case of rice straw and 35-40 bales/hour in wheat straw. The diameter and length are the same 0.64 meters for both the crop straws. The weight of wheat straw was 16 kg after 3 days and 13.6 kg after 4 days of harvest. (NARC, 2022). The testing and evaluation of the performance was conducted on station at the Directorate of Agricultural Research (DoAR), Madesh Province, Parwanipur and on farm at the Project Unit Zone of the Prime Minister Agriculture Modernization Project (PMAMP), Bagmati Province, Chitwan. A promotional leaflet on the Round Baler has also been developed to disseminate the technology among the farmers. (Annex-10).

Figure 24: Straw reaper

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Straw reapers are widely used to reap standing wheat straw after combine harvesting in the far-west and mid-west Terai. The straw reaper is operated by a tractor and a trailer is attached at the back to collect the chopped straw. This straw is then transported to the settlement, stored in bulk and fed to livestock during lean season. The demand for such wheat straw is quite high. Hence, these machines come from India along with combine harvesters for custom hiring during the wheat harvesting season.

Straw used as fertilizer: Straw is normally collected and stored nearby the settlement and is generally used as bedding materials for animals and to feed livestock in a loose form in the stall shelters. The livestock stalls are generally cleaned every day. The dung and urine, along with remaining feed and bedded straw, are collected and dumped into a nearby composting pit, which decomposes after some time and is returned to the field for use as organic fertilizer.

Straw used as base materials: Straw has been used as base materials since ancient times for different purposes. Some of them are as below:

- **Mushroom cultivation:** Paddy straw is widely used as a substrate for the cultivation of oyster and white button mushrooms after sterilization and fermentation. It is considered the best substrate for high protein content and yield of mushrooms. The shed for mushroom production is also made of paddy straw over the plastic sheet lining. This technology is widely used across the country, but the volume of straw consumption is negligible as compared to production. Machines to make balls of straw and package them into plastic bags are used in some commercial mushroom cultivating farms. In general, 1 kg of dry paddy straw produces 700-800 g of oyster mushroom. It is estimated that nearly 105,000 tonnes of rice straw with a value of NPR 52,500,000 (NPR 5/kg) have been used annually for oyster mushroom cultivation. The common field mushroom and many other types of mushrooms grow well on compost made from paddy straw. The organic matter left over after mushroom harvest can also be used as fertilizer (Bhandari and Kafle, 2017).

- **Cooking and heating fuel:** Paddy straw is an energy source to supplement the fuel wood for cooking food. The use of cow dung cakes as cooking fuel is common in rural households where access to other sources of energy is not available or for those who cannot afford to pay for modern forms of energy. The different types of straw are mixed with cow dung to make it stiff; then dried in the sun to make cow dung cakes which are burned for cooking purposes. Paddy straw is also burned in open areas of settlements, called *ghoor* in the local language, to keep warm during cold waves in the winter. Burning cow dung cakes also keep mosquitos away from people and livestock. The volume of consumption is less as compared to production.
- **Bedding material:** In general, rural households use paddy straw for bedding for domesticated livestock. This bedded straw, after getting wet, is dumped into composting pits and finally used as fertilizer.

Figure 25: Straw storage under shed

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Straw used as fodder: The most common use of straw is for consumption as fodder. Straw is collected during the harvesting season and stored in different forms under the shed or in an open space. From ancient times, almost all rural households have a few, or at the least one domesticated livestock (e.g. cows, buffalos, bullocks) for ploughing land, producing milk, etc., and their major feed was paddy and wheat straw. There are huge quantities of loose paddy straw being transported to the mid-hill regions of eastern Nepal for off-season feeding of livestock. However, the quantity that can be transported per trip is limited due to its bulk density, which results in high transportation cost per kg of straw.

Crop residues such as paddy straw, wheat straw, corn stover, oat hay, millet and buckwheat, oil-seed crops, etc. are important sources of bulk and energy for ruminants. They meet about 32-37% of Total Digestible Nutrients (TDN) required for lean season when green fodder is scarce (Padhyoti and Karki, 2017). TDN supply from crop by-products and the milling of by-products has increased due to increased food crop production. Consequently, the deficit feed balance at the national level has dropped from 30.9% in 1980 to 20.05% in 2016-17. By ecological belt, the feed deficit was the highest in the mid-hills (-24.09%), followed by the Terai (-18.91%). The feed deficit situation in the high hills was not too poor (-3.56%) (Singh and Singh, 2019). Straw fodder is used in various forms as briefly outlined below:

<u>Chopping/chaffing of straw</u> helps to reduce straw size and make it easy to handle for enhanced palatability and digestibility. There are different types and models of machines that are in use

and available in the market.

Straw treated with urea is based upon its transformation into ammonia. The urea must be hydrolyzed into ammonia and then diffused correctly so that it fixes itself to forage and modifies it chemically. The treated straw is kept for 21 days under airtight conditions. The chopped paddy straw treated with 4% urea is fed to dairy cattle and have positive effects on the body health, milk production and crude protein and in-vitro organic matter digestibility (Paudel et al., 2015a).

Figure 26: Straw block machine

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Straw blocks are a densified mixture of 80 parts straw, 10 parts molasses, 2 parts mineral, 1 part urea and 1 part salt. Compression machines pack together loose chopped straw with the above-mentioned materials to make straw feed blocks. While this helps to overcome the difficulties of handling loose straw during transportation, such industries are not common in Nepal. Krishna Dana Udyog (KDU), one of the stakeholders of CSAM's pilot project site, is using such a machine in the Morang district of eastern Nepal. However, some initial technical issues with the machine hindered its smooth operation. The issues have now been solved with some modifications and addition of auxiliary machines such as a chaff cutter, molasses pump and pipelines and conveyor belt to lower the production cost and make it more efficient.

Densified complete feed is straw-based balanced rations for livestock during green forage scarcity period. They are available in rectangular (25 mm X 25 mm) or cylindrical (8-30 mm) blocks or pellets sizes. It is a heterogeneous mixture of feed ingredients (concentrates and roughages), which contains nutrients (proteins, carbohydrates, fibre, fat, minerals and vitamins) and also meets the dry matter requirement of the animals.

Straw Wafers are about ten times bigger than the size of straw-based densified complete feed pellets or cylinders with chemical additives and other minerals. Straw wafers are easy to transport, store and feed.

Ensilage industries are being established with increase in the prevalence of commercial livestock farming. Green maize plants are harvested and chopped into pieces or left un-chopped. They are then wrapped with plastic to make them anaerobic for storage and use.

Straw craft production for handicraft and cottage industries: Paddy straw, *paral* in local language, is used as raw materials for the production of indigenous products like floor carpets (*sukul*), ropes (*dori*), mats (*chakati*), mattress (*gundri*), shoes, stool, handbags, wall hangings, etc., and also use as holy materials in Hindu mythology. Craft production from straw is considered as cottage industries and are quite common in rural areas. Since ancient times, leisure time is used to make products and support livelihoods through selling of these products. Some of the senior citizens in the rural areas are still making such crafts as a leisure activity. The utilization of straw for craft production can be made into a professional business and commercialized to reduce the volume of straw that is burned.

Straw used as industry materials: Straw is rich in fibre which is natural cellulosic with good biodegradable properties and can be used to produce paper, panel boards, etc.

- **Paper Making:** Commercial paper making industry may use large quantity of straw. However, paper mills such as the Everest Paper Mill that were using straw for paper production in Nepal have shifted to recycled paper as raw material to produce paper.
- **Building Materials:** From ancient times until now, the rural house walls are built with hard straw reinforced and plastered on both sides with a mixture of mud, cow dung, and rice husk. The roofing of rural houses is generally thatch of wheat and/or paddy straw or any stiff straw. Commercial mushroom farms are using paddy straw as wall and roofing materials to construct mushroom cultivating tunnels. Compressed soft and hard boards of straw are available and widely used in the construction market since the 2015 earthquake.

Straw used for Energy Production: The use of straw to generate electric energy is not common in Nepal, but is practiced in neighbouring countries and other parts of the world. A study conducted by Adhikari and Denich in three agro-ecological zones (Bajhang for Mountain, Lamjung for Hill and Morang for Terai districts) in 2019 to identify the potential of using crop resides to generate energy. It was found that:

(i) There was a higher amount of crop residues in the lowlands (954 kg dry matter capita^{-1} yr^{-1}) than in the hill districts (547 kg capita^{-1} yr^{-1});

(ii) The amount of crop residue used for generation of cooking energy was higher in the hills (207 kg capita^{-1} yr^{-1}) than in the lowland district (152 kg capita^{-1} yr^{-1}).

(iii) In the mountain district, crop residue production was 263 kg capita^{-1} yr^{-1}, of which 26 kg capita^{-1} yr^{-1} was used for energy generation.

(iv) The annual per capita energy equivalent from crop residues in the lowland, hills and mountains are 2.49, 3.42 and 0.44 GJ which represent 30 %, 33 % and 3 %, respectively, of total annual cooking energy consumption of the country (Adhikari and Denich, 2019).

6. Current gaps and challenges

Crop residue open burning is a steadily growing problem across the Indo-Gangetic Plain, where Nepal is not excluded. Farmers and policy makers do not have sufficient awareness of the importance of straw as a valuable natural resource with multi-dimensional uses. The study has pointed out some of the current gaps and challenges as mentioned below:

<u>Policy</u>: Nepal has various policies and strategies that support the agricultural growth of the nation. In 2004, when the National Agriculture Policy came into action, none of the sections

considered agricultural mechanization as important. The perception at that time was it would replace agricultural labour. However, Nepal is now experiencing an outmigration of people from rural areas and increased urbanization. This is creating a scarcity in the availability of agricultural labour and has brought agricultural mechanization onto the policy agenda. The AMPP was introduced in 2014 with four objectives, which have created a conducive environment to expand mechanization along with the use of combine harvesting technology in the country. The ADS, which presents a 20-year vision, is silent on the issue of CROB. In recent years, the expansion of CH use has generated CROB problems, which AMPP and ADS do not directly address. It is difficult to advocate the policy makers to address these gaps in updating AMPP or provincial ADS, as this issue is a new development due to rapid use of CH and do not show immediate impact in soil, environment and health.

Data: Concerned offices do not have relevant statistical information on the availability and utilization of straw resources. Straw yield is not considered as an important item, when registering new or imported varieties of crop, only grain yield is recorded. There are difficulties in calculating straw quantity, since the straw-grain ratio varies depending on crop varieties and agro-ecological differences. The harvest index of other countries or locations are also not suitable for calculation of straw yield in the context of Nepal. National planning for integrated straw management (ISM) is hampered by the lack of data on quantity of straw burning, technologies for straw management being used and quantity of straw being utilized. There is a huge gap in statistical data on agricultural machinery in the country. The import data from the Department of Customs does not match with combine harvesters and tractors registered with the Transport Office. There is a need to create a database on agricultural machinery and ISM related issues.

Irrigation: Unavailability of year-round irrigation for cereal cultivation is another gap that compel farmers to depend on the monsoon for two consecutive crop cycles annually. Farmers harvest paddy in October/November and plant wheat within the same month and harvest it in April/May. The dependency on rain-fed irrigation makes the turnaround time very tight. Farmers consequently clear the land of crop stubble through the quickest and cheapest way, i.e., by setting the residue on fire in combine harvested fields. Access to irrigation can lengthen this turnaround time, but immediate access to irrigation is difficult as there is a need for huge investments and long-term planning for reliable irrigation.

Fertilizer: All inorganic fertilizers in Nepal are imported, and it is one of the inputs that can enhance production while simultaneously degrading the soil structure. Soil structure can be improved by adding organic matter from in-situ straw management practices or ex-situ practices of making organic fertilizers by decomposing crop straw with livestock waste and returning it back to field. There are several organic fertilizer industries in the country, and the government should enforce the use of crop straw residue as raw material to produce organic fertilizers.

Agricultural Labour: Severe shortage of agricultural labour, especially during the planting and harvesting of crops, is another gap. The outmigration of youth from rural areas, particularly for men engaging in non-agriculture employment, has forced the adoption of mechanized agricultural practices. Male labour shortages have also added workload on women and forced the harvesting of cereal crops by combine harvesters. The majority of farming households clear their land by burning crop stubble due to additional investment for collection, lack of market for straw, etc. The agricultural labour shortage issue is global and the main challenge is to attract youth in agriculture with a new vision and incentives.

<u>Mechanization of Agriculture</u>: Severe labour shortages and feminization of farming families has led to an increased use of CH. Hiring services for harvester charge on the basis of area covered. This tends to leave long stubbles in the field as service providers try to harvest fields as quickly as possible by cutting only the panicles of cereal crops. This long stubble of more than 300 mm is difficult to manage, needs special machines and is unlikely to decompose in time for the subsequent planting season, so such land areas are cleared out by burning. The main challenge is to change the system of hiring services to charge on a time basis to reduce the amount of stubble left in the field or improve access to straw management machines like balers and reapers to facilitate the extraction of straw from the field. The improvement of access to conservation agriculture machines like Happy seeders, super seeders, eco-seeders, zero-till drills is also an alternative to reduce the burning of crop residues.

Figure 27: Combine harvester with long stubbles

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<u>Animal Husbandry</u>: There is a steady decline of traditional farming households practicing small-scale agriculture and livestock rearing. The decrease in the number of household members and loss of common grazing lands are leading people to discontinue animal husbandry. Commercial farmers switching to new forms of feed has reduced the consumption of crop straw. This reduces the uses of crop residue which leads to increased burning. Promoting livestock in each farmer household is a challenge as it requires an integrated approach of the farming system with greater us of organic fertilizers than inorganic ones.

<u>Straw Management Technique</u>: The straw management techniques are also not widely adopted due to the lack of a reliable market for straw, affordable technologies, alternative method of utilization, and/or its products. Hence, farmers find it easier to burn stubble rather than use alternate straw management techniques. The paper industry used to be a bulk consumer of paddy straw, but now almost none are using it. There is no industry making bio-char from straw in the country. Other huge consumption sources for straw are livestock feed and base materials for mushroom cultivation. To establish a reliable straw market, the government should prioritize these industries and provide incentives if needed.

<u>Energy use</u>: The shift in energy use from the more polluting fuelwood and dung cakes to LPG and even electricity is a positive aspect of improving lifestyle and health. This has reduced the use of straw as cooking fuel or to make dung cakes for domestic cooking by farming households. The promotion of straw used as raw materials for domestic biogas should be

considered.

Misleading perceptions: Farmers believe that crop residue burning is good for both plants and the soil as it helps to control pests, weeds, and diseases. The burning of straw is the cheapest and most practical option for farmers as they feel there is no alternative use for straw and that ash also works as a fertilizer. However, the burning of crop residue contributes to soil degradation from the loss of nutrients and organic matter. The fires kill plants and insects that are good for the land. It also increases soil erosion, which prompts the need for additional fertilizer and soil management inputs. Changing the mind-set of farmers is the most difficult task, and this process may take time.

Agriculture Feminization: Male outmigration is radically changing rural socio-cultural dynamics. Women need to take on additional responsibilities for managing the agriculture system in addition to their household activities. Women are taking charge of male responsible activities such as ploughing, but they also have to adapt to the new non-traditional community dynamics like attending local meetings and actively managing farms differently. Hence, providing access to women-friendly machines to reduce work burdens and save time is a major challenge.

Technology: ISM is an upcoming new technology for efficient utilization of crop residue in Nepal. There are no adequately trained technicians with knowledge of in-situ and ex-situ straw management techniques.

Coordination: There is a coordination gap between research, education, extension institutions, and the private sector. The promotion of ISM and proper utilization of crop residue requires strong coordination among various stakeholders.

The main challenge is how to fill identified gaps, advocate on the negative impacts that straw burning has on the soil, environment and health, and educate farmers on the importance of stopping the burning of straw with the adoption of different techniques that better use straw and reduce adverse environmental effects.

If crop residue open burning (CROB) is not controlled, it can lead to various issues. Among those are reduction in atmospheric visibility, deterioration of air quality, adverse impact on climate through the release of greenhouse gases, and an increase in the country's economic loss. It could also trigger severe health impacts like respiratory and cardiovascular disease, allergies and premature deaths, and increase asthma attacks among children and people of old age.

7. Opportunity and recommendation

In order to tap the unrealized opportunities that alternative uses of crop residue can have to improve farmers' livelihoods and the environment, the following are the recommendations for Nepal to start a **"no burn"** campaign.

Policy Support: The Federal government should consider ISM as an integral part of farming systems in Nepal and revise/modify or update the AMPP. Provincial governments are in the process of preparing provincial agriculture policies and strategies as per the need of their local situations, and it is recommended that ISM be considered as one of the integral parts of upcoming documents. Strong policy interventions are required to discourage CROB, with incentives for adopting appropriate mechanization, developing markets for straw use and dis-incentives for crop residue burning.

Law Enforcement: The 20 April 2015 decision on restricting the import of combine harvesters or seasonal service providers entering Nepal without straw management machines like balers, reapers, etc., should be strictly implemented and monitored. This should also be strictly followed by provincial transport offices when registering new combine harvesters. Provincial and local government extension offices should have the authority to penalize non-compliant service providers.

Data Support: National sample censuses of agriculture have started including data of a few agricultural tools and machines since 1991-92. There is a need to update data to include new types of machines like combine harvesters, which are in use after 2000. The MOALD statistical yearbook needs to include statistics on machine use in the country, which is currently lacking. Data of straw yield along with grain yield during crop cutting should be collected to obtain figures on the quantity of straw produced in the country. Data on quantity of straw burning and technologies for straw management is lacking, availability will help to plan ISM interventions.

Irrigation Facility: Improving the availability of year-round irrigation for cereal crops can ease the turnaround time between paddy harvesting and wheat planting as farmers should not rely on winter rain for land preparation and they will find adequate time to manage crop residue left by using CH. Access and improvement of irrigation facilities can be managed by government's commitment with long term planning.

Fertilizer Facility: The Government should plan to return at least 75% of crop straw back to the field either by in-situ or ex-situ straw management practices. This will improve soil health which is being degraded by chemical fertilizer use. Good quality compost fertilizers and bio-char can be produced from crop residues. The Government should promote existing and new organic fertilizer factories to use crop residues by subsidizing the product and providing interest rate subsidies for capital investments financed by financial institutes. These types of factories can handle large amounts of straw, ensure a reliable market for straw and ultimately improve levels of soil organic matter and soil quality.

Attracting Youth: To stop youth migration from agriculture, the government should have a new vision and ideas to retain youth in this sector. The provision of incentives for using new technology, subsidies for machines, investments in establishing modernized farms, training in ISM techniques, and developing market assurance for products made from crop straw residue.

Mechanization Solutions: Popularization and adoption of technologies like the happy seeder, super seeder, and eco-seeder can be an option to facilitate the management of crop residue after the use of combine harvesters. The provision of subsidies to purchase such expensive equipment in collective/group or cooperative basis for leasing could help smallholder farmers who otherwise cannot afford to buy them. Straw baler/reaper harvesting technologies can also be deployed to collect remaining residue from the field. Residue spreaders can distribute loose crop residue uniformly. The potential introduction of Conservation Agriculture (CA) based machineries like zero tillage (ZT) or minimum tillage machines can play a pivotal role to ameliorate soil fertility and minimize emissions from agricultural crop residue burning. Mechanization packages should be developed, such as the mandatory purchase of a Happy or Super seeder, straw chopper, or baler when buying a combine harvester. The restriction in importing CH without these machines should be strictly enforced.

Changing hiring systems: Custom hiring systems for CH in Nepal mostly charge farmers on an area basis. The changing of hiring charges from an area to a time basis might be a solution to leave short stubble in the field, which will reduce open burning. If this cannot be enforced for individual service providers, it can be done for group or cooperative owned CH. Farmers should be advised to prioritize the group or cooperative owned CH that charge on a time basis for services rendered. This can ensure the extraction of more straw by keeping the stubble height as low as possible so that simple cultivators or rotavators can incorporate residue into the soil without the need for additional straw management machines.

Raising Livestock: Encouraging the rearing of livestock by individual rural farm households with an integrated farming method would be a viable option to consider for mitigating the burning of crop residue to a certain extent. It can improve farming systems by utilizing crop straw as fodder, bedding material, and composting for use as fertilizer. Raising livestock such as cows and buffaloes will add nutrients to their diet by the milk produced, and it is sustainable integrated agriculture approach in various social and economic aspects.

Straw Management Options: Lack of alternative ways of disposing of crop residues is the main reason behind open burning in the field. It is therefore vital to address this issue by promoting alternate ways of disposing the crop residues or incorporating into the soil. The government should plan to return at least 75% crop residue back to the soil.

- In-situ straw management is through mulching or incorporating crop straws into the soil as fertilizer. It is the best option to improve soil health, while simultaneously reducing the use of chemical fertilizers. This can ease the turnaround time between two major crops but requires specialized machines, which can only be achieved with a strong commitment from the government to the farmers.
- Ex-situ straw management is use of crop residue as raw materials for industries like brick kilns, paper production, mushroom cultivation, for alternative energy production like biogas, bio-briquette, pellets, and fodder production like feed blocks, densified feed pellets, wafers, etc. It needs professional planning and careful financial calculations to establish straw-based businesses. For all these, a functional straw market with reasonable prices is needed with government financial support such as through the provision of capital and interest subsidies to establish straw-based industries and/or buy back guarantees if

products like manure, bio-char, feed blocks are not sold in the market. If such industries are established, it makes the straw market reliable. A simple alternative solution could be to provide subsidies for farmers who collect crop straw. This technique and straw-based industries can manage huge quantity of straw and help the **"no-burn"** campaign of the nation.

Improve Agricultural Practices: Incorporating crop residues into the soil positively impacts the microbial population and increases nutrients in the soil. Not burning crop residue prevents significant air pollution, retains soil nutrients, and increases soil organic matter, leading to improved agricultural productivity. CA can counter resource degradation and introduce resource efficiency. Crop residue for mulching can improve long term soil fertility and productivity.

Capacity Building, Awareness Raising and Changing Perceptions of Farmers: The raising of awareness on the negative impacts of CROB on human health and the environment through media campaigns and community awareness programmes should be a top priority of local governments to change the perceptions of the farmers. The provision of trainings on managing crop residue such as ploughing stubble back into the soil, making bio-char, compost manure, biofuels, etc., is the most important aspect of achieving a **"no-burn"** campaign.

Adoptive Research & Piloting Technology: Adoptive research should be carried out on technologies proven to be successful in other countries for validation and modification, if required, to suit the national context. The best approach is to pilot a proven technology after adoptive research and disseminate it for wider adoption.

Coordinated Approach: For the success of the technology, there should be strong coordination and cooperation among research, education and extension agencies.

Incentive for not burning: Signing an agreement for a payment to stop smallholder farmers from burning crop straw could be an approach for achieving the goals of a **"no-burn"** campaign.

8. Follow-up actions

The burning of open crop residue is spreading all over the Terai, with increasing use of combine harvesters due to the scarcity of labour during the harvesting season. Based on the findings of this study, the implementation of a **"no-burn"** action plan to stop or reduce CROB is proposed with actions to be taken in the short, medium and long terms.

Short Term

- Conduct a baseline survey on the existing status of availability of straw and utilization to understand location-wise demand and utilization patterns in different areas across the country.
- Initiate some nationwide activities like a FM jingle, postering, miking, leaflet, etc. for a **"no-burn"** campaign to stop CROB. (Leaflet example as Annex- 13 & 14).

- Change the combine harvester hiring service charge from an area-based to a time-based approach.
- Enforce requirement on importing of straw management machines along with CH.
- Provide incentives for not burning.
- Provide subsidies for ISM technologies and machines with no direct subsidies for CH.
- Pilot best practices of in-situ and ex-situ ISM and replicate learning to other locations.
- Raise awareness of the impact of CROB on the environment and soil health through radio, poster, audio and video campaign.
- Advocate to policy makers on the importance of straw management and the consequences of CROB.

Medium Term

- Validate and adopt the best practices from the neighbouring countries.
- Develop and implement a programme like training, demonstration, showcase etc. to promote straw collecting machinery and their usage.
- Promote practice of conservation agriculture (CA) by providing subsidies in time bound manner.
- Include and prioritize crop residue utilization in the upcoming "Feed and Fodder Policy" of federal government.

Long Term

- Undertake further action to include ISM in the policy and strategy of federal and provincial governments to reduce and finally stop CROB.
- Plan that 75% of crop residue are returned back to the field either by in-situ or ex-situ management to improve the soil health and reduce the use of chemical fertilizers.

9. Conclusions

Crop residue open burning in Nepal started after the introduction of combine harvesters in the country. Government agencies/policymakers promoted CH through various schemes. Through these promotional activities, the use of CH is rapidly increasing as well as incidences of CROB. After realizing the consequences of burning, the government enforced restrictions on the importing of CH without straw management systems, but complete zero burning cannot be achieved. This is due to the unavailability of straw collecting machines, alternate technologies for planting succeeding crops in long stubble, short turnaround time between rice harvesting and wheat planting, shortage of agriculture labour due to migration, lack of knowledge/opportunity/markets on alternative uses, unawareness of the impacts on the environment and on soil health.

It is recommended that the "changing of combine harvester rental service charges from an area-based to a time based" system might be the first solution to leave short stubble in the field that can easily be ploughed by widely available cultivator or rotavator in the local machinery market. For this transformation to take place, CH service providers should be educated on the negative impact of burning, advocate for their social responsibility and finally change their mind-set to charge on a time basis. If this cannot be enforced for individual service providers, it can be done through group or cooperative owned CH.

Finally, the government should plan to return back at least 75% of crop residue to the field either by in-situ or ex-situ management techniques to improve the soil health and reduce the use of chemical fertilizer as part of the long-term action plan to achieve the goals of the **"no-burn"** campaign of the nation.

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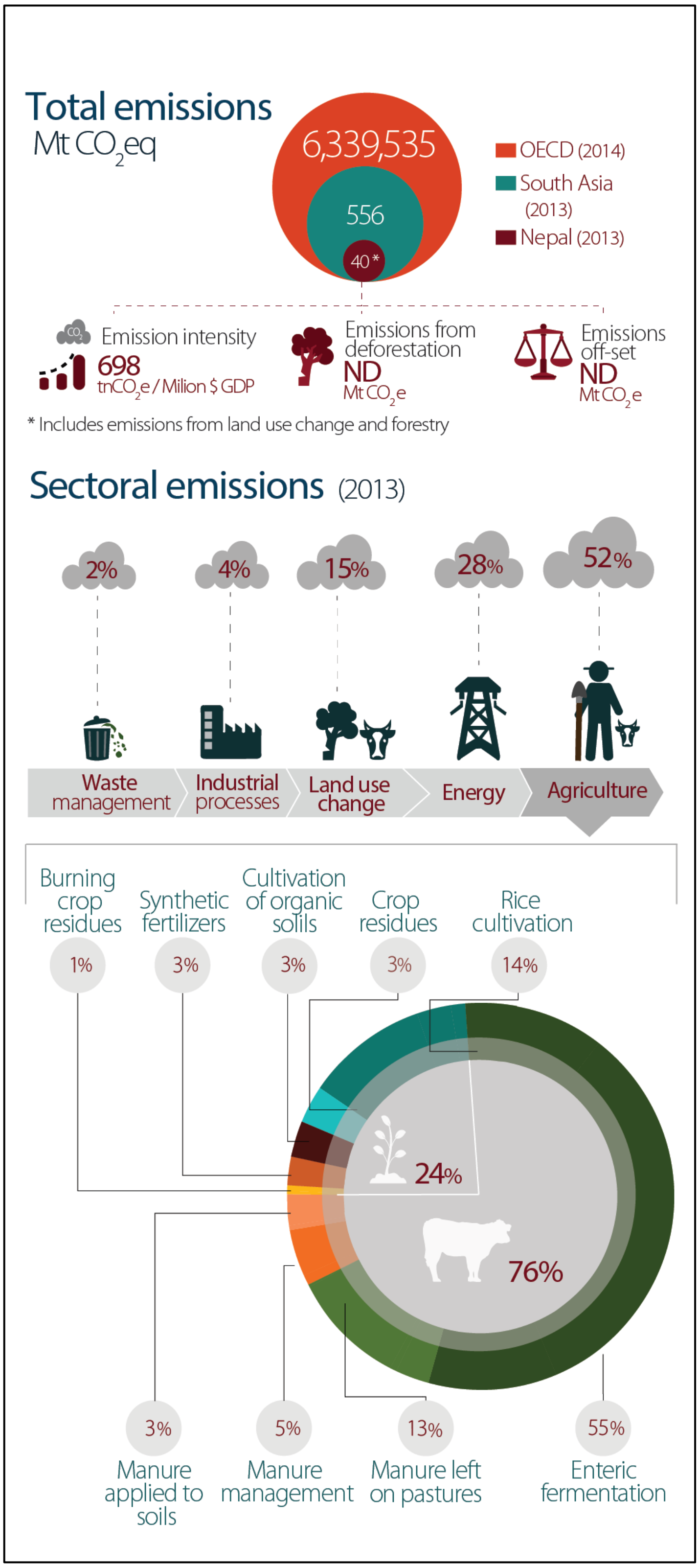
Annex 1: Sectoral Emissions



Source: CIAT. World Bank, CCAFS and LI-BIRD (2017)

Annex 2: Notice for banned in import of combine harvester without straw management machine such as baler or straw reaper.

नेपाल राजपत्र

नेपाल सरकारद्वारा प्रकाशित

खण्ड ६५) काठमाडौं, बैशाख ७ गते, २०७२ साल (संख्या १

भाग ५

नेपाल सरकार

वाणिज्य तथा आपूर्ति मन्त्रालयको सूचना

नेपाल सरकारले निकासी पैठारी (नियन्त्रण) ऐन, २०१३ को दफा ३ को उपदफा (१) ले दिएको अधिकार प्रयोग गरी खण्ड ५९, संख्या २८, मिति २०६६ कार्तिक १६ गतेको नेपाल राजपत्र भाग ५ मा प्रकाशित आदेशको प्रकरण ४ को खण्ड (ङ) पछि देहायको खण्ड (ङ१) थप गरेकोले यो सूचना प्रकाशन गरिएको छ।

"(ङ१) स्ट्र कलेक्टर वा बेलर विनाको कम्बाइन्ड हार्भेष्टर, ।"

आज्ञाले,

इन्द्र प्रसाद उपाध्याय

नेपाल सरकारको सचिव

मुद्रण विभाग, सिंहदरबार, काठमाण्डौमा मुद्रित । मूल्य रु ५।-

मो.हु.द.नं. १६।०६२।०६३

आधिकारिकता मुद्रण विभागबाट प्रमाणित गरिएपछि मात्र लागू हुनेछ।

Annex 3: Production and Price of Grain and Rice Straw in Hill districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Prod. (kg/ha)	Grain Price (NPR/ kg)	Straw Prod. (kg/ha)	Straw Price (NPR/ kg)	Straw Grain Ratio
1	Taplejung	Khumal-2	Rainfed	4,527.9	22.6	4,978.8	1.55	1.10
2	Panchthar	Local	Irrigated	3,342.5	21.25	3,678.1	1.41	1.10
3	Dhankuta	Local	Rainfed	3,240.1	23.5	3,562	1.40	1.10
4	Udaypur	Local	Rainfed	3,461.2	25.36	3,807.6	1.42	1.10
5	Sindhuli	Radha-7	Rainfed	3,920	22.5	4,310.5	1.38	1.10
6	Dolakha	Khumal-3	Irrigated	4,251.8	22.08	4,676.9	1.32	1.10
7	Sindhupalchock	Khumal-4	Rainfed	4,392.5	22.45	4,830.1	1.32	1.10
8	Kavrepalanchok	Khumal-2	Irrigated	4,185.9	22.45	4,606	1.35	1.10
9	Kathmandu	Khumal-11	Rainfed	4,974.3	23.51	5,471.7	1.42	1.10
10	Dhading	Mithila	Rainfed	4,227.01	22.42	4,650.1	1.35	1.10
11	Makwanpur	Palung-2	Rainfed	4,873.3	22.3	5,358.2	1.33	1.10
12	Lamjung	Sabitri	Irrigated	3,620	23.5	3,983.2	1.48	1.10
13	Gorkaha	Local	Rainfed	3,185.4	25.7	3,502	1.42	1.10
14	Tanahun	Local	Rainfed	3,223.9	24.6	3,545	1.48	1.10
15	Syangja	Sunaulo Sughandha (high value)	Irrigated	3,760	21.8	4,136.8	1.47	1.10
16	Kaski	Local/Ekle Jaat	Irrigated	3,460.02	25.6	3,808	1.52	1.10
17	Myagdi	Khumal-5	Rainfed	4,495.3	22.41	4,941.8	1.53	1.10
18	Parbat	Khumal-9	Rainfed	4,455.8	22.56	4,900	1.42	1.10
19	Baglung	Local	Rainfed	3,288.2	23.8	3,660.1	1.54	1.11
20	Gulmi	Local	Irrigated	3,518.5	22.9	3,871.2	1.48	1.10
21	Palpa	Khumal-8	Rainfed	4,245	22.4	4,665.3	1.48	1.10
22	Salyan	Khumal-3	Rainfed	4,378.8	22.44	4,817.2	1.48	1.10

SN	Districts	Variety	Irrigation	Grain Prod. (kg/ha)	Grain Price (NPR/ kg)	Straw Prod. (kg/ha)	Straw Price (NPR/ kg)	Straw Grain Ratio
23	Surkhet	Khumal-8	Rainfed	4,267.3	22.4	4,692.9	1.41	1.10
24	Dailekh	Khumal-3	Rainfed	3,964.8	22.45	4,360.2	1.42	1.10
25	Jajarkot	Khumal-8	Rainfed	4,496.4	22.41	4,945.8	1.45	1.10
26	Jumla	Chandannath	Irrigated	4,267.3	25.2	4,694	1.42	1.10
27	Bajura	Local	Rainfed	3,821.1	23.41	4,203	1.46	1.10
28	Bhajhang	Local	Rainfed	3,514.3	23.41	3,862.8	1.43	1.10
29	Doti	Local	Rainfed	3,798	24.8	4,185	1.52	1.10
30	Baitadi	Rampur Masuli	Rainfed	3,953.89	23.6	4,350	1.48	1.10
31	Nuwakot	Kanchan	Irrigated	3,662.5	22.61	4,027.8	1.33	1.10
	Hill	**Total**		**122,773.02**	**718.42**	**135,082.1**	**44.47**	**34.11**
		Average		**3,960.42**	**23.17**	**4,357.49**	**1.43**	**1.10**

Source: Calculated from data in Department of Agriculture (2018)

Annex 4: Production and Price of Grain and Rice Straw in Terai districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
1	Jhapa	Radha-12	Irrigated	3,822.65	22.6	4,206	1.42	1.10
2	Jhapa	Hardinath-1	Irrigated	4,080.9	22.6	4,490	1.3	1.10
3	Morang	Radha-13	Irrigated	4,251.8	22.41	4,676	1.35	1.10
4	Morang	Chaite-2	Irrigated	3,970	22.8	4,367.08	1.3	1.10
5	Sunsari	Sabitri	Rainfed	3,950.2	22.72	4,345	1.42	1.10
6	Sunsari	Chaite-2	Irrigated	3,840	22.8	4,222.9	1.3	1.10
7	Saptari	Janaki	Irrigated	3,461.2	25.36	3,807.6	1.42	1.10
8	Siraha	Masuli	Irrigated	3,461.2	22.6	3,808.2	1.29	1.10
9	Dhanusa	Janaki	Irrigated	4,022.03	22.34	4,424.8	1.38	1.10
10	Dhanusa	Chaite-2	Irrigated	3,562	22.5	3,920	1.29	1.10
11	Mahottari	Mithila	Irrigated	4,023.2	22.54	4,425	1.38	1.10
12	Mahottari	Hardinath-1	Irrigated	3,970.5	22.64	4,367.4	1.28	1.10
13	Sarlahi	Radha-9	Irrigated	3,610.8	22.41	3,940.8	1.42	1.09
14	Rautahat	Sabitri	Irrigated	3,988.9	22.5	4,389	1.42	1.10
15	Bara	Radha-11	Irrigated	3,718.9	22.5	4,091.5	1.48	1.10
16	Parsa	Sabitri	Irrigated	3,525	22.45	3,877.4	1.48	1.10
17	Chitwan	Rampur Masuli	Irrigated	4,029	23.4	4,431.9	1.48	1.10
18	Chitwan	Hardinath-1	Irrigated	4,424.8	23.1	4,865.8	1.29	1.10
19	Nawalparasi	Radhakrishna-9	Irrigated	3,486.9	22.5	3,835.2	1.32	1.10
20	Rupandehi	Rampur Masuli	Irrigated	3,883.5	22.45	4,270.8	1.35	1.10
21	Kapilbastu	Janaki	Irrigated	3,939.5	22.44	4,332.1	1.3	1.10
22	Dang	Bindeshwori	Irrigated	4,022	22.54	4,423	1.32	1.10
23	Banke	Radhakrishna-9	Irrigated	3,682	22.5	4051.9	1.36	1.10

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
24	Bardiya	Radhakrishna-9	Irrigated	3,726.1	22.41	4,098.5	1.35	1.10
25	Kailali	Rampur Masuli	Irrigated	4,362.89	22.5	4,798.9	1.32	1.10
26	Kanchanpur	Masuli	Rainfed	4,163.85	21.8	4,582.3	1.31	1.10
	Terai	**Total**		**100,979.82**	**589.41**	**111,049.08**	**35.33**	**28.59**
		Average		**3,883.84**	**22.67**	**4,271.12**	**1.36**	**1.10**
	Hill and Terai Average			**3,922.13**	**22.92**	**4,314.30**	**1.40**	**1.10**

Source: *Calculated from data in Department of Agriculture (2018)*

Annex 5: Production and Price of Grain and Maize Straw in Hill districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
1	Taplejung	Sitala	Rainfed	4,152	21.6	4,851.5	0.55	1.17
2	Dhankuta	Manakamana-4	Rainfed	4,284.9	18.4	4,899	0.61	1.14
3	Terathum	Ganesh-1	Rainfed	3,968	20.1	4,570	0.62	1.15
4	Okhaldhunga	Manakamana-4	Rainfed	4,120	18.6	4,681.3	0.61	1.14
5	Sindhuli	Manakamana-3	Rainfed	4,200	19.1	4,752	0.6	1.13
6	Kaverpalanchowk	Khumal Pahelo	Rainfed	4,132	20	4,756.3	0.6	1.15
7	Lalitpur	Manakamana-4	Rainfed	4,110	18.5	4,765	0.6	1.16
8	Dhadhing	Khumal Pahelo	Irrigated	4,110	19.5	4,752	0.55	1.16
9	Gorkha	Deuti	Rainfed	4,235.5	19.3	4,899	0.58	1.16
10	Kaski	Poshilo Makai-1	Irrigated	4,106	19.62	4,758	0.6	1.16
11	Baglung	Manakamana-3	Rainfed	4,162	19.23	4,782.5	0.55	1.15
12	Gulmi	Rampur Composite	Rainfed	4,012	18.45	4,610	0.53	1.15
13	Palpa	Deuti	Rainfed	4,110	18.25	4,720	0.59	1.15
14	Pyuthan	Manakamana-6	Rainfed	3,961.8	19.39	4,458	0.61	1.13
15	Rolpa	Manakamana-5	Rainfed	4,038.9	19.82	4,610	0.61	1.14
16	Salyan	Manakamana-6	Irrigated	3,976	19.6	4,569	0.52	1.15
17	Surkhet	Sitala	Irrigated	3,926.1	19.1	4,502	0.57	1.15
18	Jajarkot	Manakamana-6	Rainfed	3,994	19.5	4,580	0.62	1.15
19	Jumla	Manakamana-6	Rainfed	4,027.1	19.85	4,620	0.57	1.15
20	Doti	Manakamana-3	Rainfed	4,075.6	18.98	4,670.9	0.58	1.15
	Hill	**Total**		**81,701.9**	**386.89**	**93,806.5**	**11.67**	**22.96**
		Average		**4,085.10**	**19.34**	**4,690.33**	**0.58**	**1.15**

Source: *Calculated from data in Department of Agriculture (2018)*

Annex 6: Production and Price of Grain and Maize Straw in Terai districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
1	Jhapa	Gaurab	Irrigated	4,605	18.1	4,980	0.72	1.08
2	Sunsari	Gaurab	Irrigated	4,398	18.23	4,899	0.61	1.11
3	Siraha	Rampur-2	Irrigated	4,010	19.5	4,750	0.6	1.18
4	Sarlahi	Rampur Composite	Irrigated	4,110	19.5	4,750		1.16
5	Parsa	Rampur Composite	Irrigated	3,950	18.5	4,492	0.6	1.14
6	Chittwan	Hybrid	Irrigated	4,812	19.2	5,440.2	0.6	1.13
7	Rupandehi	Arun-1	Irrigated	3,956.8	18.62	4,531	0.55	1.15
8	Kapilbastu	Rampur Composite	Irrigated	4,102	18.9	4,627.3	0.52	1.13
9	Dang	Arun-1	Irrigated	4,189.3	19.8	4,809	0.55	1.15
10	Kailali	Gaurab	Irrigated	4,428.5	19.8	4,899	0.57	1.11
	Terai	**Total**		**42,561.6**	**190.15**	**48,177.5**	**5.32**	**11.33**
		Average		**4,256.16**	**19.02**	**48,17.75**	**0.53**	**1.13**
		Hill Terai Average		**4,170.63**	**19.18**	**4754.04**	**0.56**	**1.14**

Source: Calculated from data in Department of Agriculture (2018)

Annex 7: Production and Price of Grain and Wheat Straw in Hill districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
1	Panchthar	Annapurna-3	Irrigated	3,198.8	23.1	3783	1.05	1.18
2	Sankhuwasabha	Pasang Lahmu	Rainfed	3,195	23.8	3,320	1.06	1.04
3	Bhojpur	Annapurna-4	Irrigated	3,220.4	23.6	3,500.6	1.5	1.09
4	Khotang	Kanti	Rainfed	3,311	22.3	3,472	1.05	1.05
5	Udaypur	Achut	Irrigated	3,294.8	23.57	3,436	1.09	1.04
6	Dolakha	Annapurna-4	Irrigated	3,247.8	23.3	3,650	1.25	1.12
7	Bhaktapur	BL-1135	Irrigated	3,861.2	22.89	3,598.8	1.48	0.93
8	Nuwakot	Lerma-2	Irrigated	3,292.5	22.68	3,598.8	1.38	1.09
9	Rasuwa	Annapurna-4	Rainfed	3,289.5	22.98	3,430	1.38	1.04
10	Makawanpur	Annapurna-1	Rainfed	3,321.2	22.6	4276.9	1.48	1.29
11	Tanahun	Lerma-52	Irrigated	3,148.9	23.4	3,541.5	1.42	1.12
12	Kaski	Annapurna-3	Irrigated	3,258.9	23.5	3,658.9	1.48	1.12
13	Manang	Pasang Lahmu	Rainfed	3,138	24.5	,3539.9	1.38	1.13
14	Palpa	Lerma-52	Irrigated	3,329.6	22.6	3,519.9	1.38	1.06
15	Arghakhachi	Annapurna-1	Irrigated	3,351	22.6	3,539.8	1.38	1.06
16	Rukum	Kanti	Rainfed	3,085.6	25	3,451.2	1.51	1.12
17	Salyan	Annapurna-4	Irrigated	3,106	23.6	3,342.5	1.38	1.08
18	Surkhet	Kanti	Irrigated	3,110	23.04	3425	1.48	1.10
19	Jumla	Pasang Lahmu	Irrigated	3,210	24.78	3,668.5	1.42	1.14
20	Kalikot	Annapurna-1	Rainfed	3,009.5	24.5	34,35	1.38	1.14

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
21	Bajura	Pasang Lahmu	Rainfed	2,971.2	24.5	3,219.6	1.38	1.08
22	Accham	Gaura	Rainfed	2,929.8	22.68	3,517.98	1.38	1.20
23	Dadeldhura	Gaura	Rainfed	3,220	22.6	3,621.8	1.38	1.12
	Hill	**Total**		**74,100.7**	**538.12**	**81,547.68**	**31.07**	**25.36**
		Average		**3,221.77**	**23.40**	**3,545.55**	**1.35**	**1.10**

Source: Calculated from data in Department of Agriculture (2018)

Annex 8: Production and Price of Grain and Wheat Straw in Hill districts in FY 2017-18

SN	Districts	Variety	Irrigation	Grain Production (kg/ha)	Grain Price (NPR/kg)	Straw Production (kg/ha)	Straw Price (NPR/kg)	Straw Grain Ratio
1	Jhapa	NL-297	Irrigated	3,352	22.1	3410	1.55	1.02
2	Morang	NL-297	Irrigated	3,335	22.5	3608	1.44	1.08
3	Saptari	BL-1473	Irrigated	3,386	23.41	3,541.9	1.45	1.05
4	Siraha	BL-1135	Irrigated	3,401	23.1	3597	1.55	1.06
5	Sarlahi	BL-1135	Irrigated	3,208	22.6	3598	1.48	1.12
6	Rautahat	Bhrikuti	Irrigated	3,328.1	22.6	3,628.9	1.48	1.09
7	Bara	NL-297	Irrigated	3,398.5	22.6	3,480.2	1.48	1.02
8	Chitwan	NL-971	Irrigated	3,421	22.8	3,732.8	1.48	1.09
9	Rupandehi	Achut	Irrigated	3,362.6	22.78	3,422.8	1.42	1.02
10	Kapilbastu	NL-297	Irrigated	3,208	22.78	3,608	1.42	1.12
11	Dang	BL-1022	Irrigated	3,220	24.3	3,624.5	1.35	1.13
12	Bardiya	Aditya	Irrigated	3,108	23.5	3,445	1.48	1.11
13	Kailali	Bijaya	Irrigated	3,324.5	22.48	3,498.5	1.3	1.05
	Terai	**Total**		**43,052.7**	**297.55**	**46,195.6**	**18.88**	**13.96**
		Average		**3,311.75**	**22.89**	**3,553.51**	**1.45**	**1.07**
		Hill Terai Average		**3,266.76**	**23.14**	**3,549.53**	**1.40**	**1.09**

Source: Calculated from data in Department of Agriculture (2018)

Annex 9: Promotional leaflet of Turbo Happy Seeder developed by NARC, AIRS, Birgunj

ट्रेक्टरबाट संचालित टर्बो हेप्पी सिडर मेशिन

(Tractor Driven Turbo Happy Seeder)

विशेषताहरु

- टर्बो हेप्पी सिडर मेशिनबाट खेतमा रहेको पुर्वबाली अवशेषको सदुपयोग गरि धान/ गहुँको उत्पादन वृद्धि गर्न सकिन्छ ।
- कम्बाईन हार्भेष्टरबाट काटिएको धान/ गहुँको पराल जलाउने समस्याको समाधान गर्नको लागि यो मेशिनबाट धान/ गहुँको ठुटोको व्यवस्थापन गरी (छाप्रो बनाई/ हाली) विना खनजोत भएका खेतमा सिधै धान/ गहुँ लगाउने काम गरिन्छ ।
- बाली काटेको खेतमा सिधै यसको प्रयोग गर्न मिल्ने हुनाले समयमै रोपाई तथा कटाई गर्न सकिन्छ जसले गर्दा उत्पादकत्व बढ्दछ ।
- छाप्रोले गर्दा बालीहरुमा झारपात नहुने, पन्छीहरुबाट हुने बीउको नोक्सानी बाट जोगाउन र साथै सिचाई खर्च पनि जोगाउन सकिन्छ ।
- यस मेशिनमा रहेको दुईवटा गहिराई नियन्त्रण गर्ने पांग्राहरुले समान गहिराईमा र फ्लुटेड रोलर मेकेनीजमले तोकीएको मात्रामा बिउ/ मल झार्न मद्दत गर्दछ ।
- यो प्रबिधि वाताबरण मैत्री रहेको र माटोको गुणस्तर बढाउनमा मद्दत गर्दछ ।

कार्यक्षमता

- ५० अश्व शक्तिको ट्रेक्टरको पि.टी.ओ. बाट चल्ने ९- फाली रहेका यस मेशिनबाट प्रति घण्टा ०.३३ हे. अर्थात् १० कट्ठा सम्म धान/ गहुँको बिउ लगाउन सकिन्छ ।

उपयोगिता

- तराई तथा भित्री मधेशका समथर खेतमा धान/ गहुँ लगाउनमा यस मेशिनको उपयोग गर्न सकिन्छ ।

मुल्य ने.रु. ६,००,०००/- प्रति थान

नेपाल सरकार

नेपाल कृषि अनुसन्धान परिषद्

कृषि औजार अनुसन्धान केन्द्र

रानीघाट, बीरगंज, पर्सा

Source: NARC, Agriculture Implement Research Station, Birgunj

Annex 10: Promotional leaflet of Round Baler developed by NARC, AIRS, Birgunj

ट्रेक्टरबाट सचालित बेलर मेशिन

(Tractor Driven Round Baler)

विशेषताहरु

- ज्यामीको अभावले कम्बाईन हार्भेष्टरले खेतमा छोडेको पराल प्राय जसो खेतमा डढाउने/बाल्ने गर्दा एकातिर पशुलाई आवश्यक नल/ परालको कमी हुने र अर्को तिर माटोमा भएका मित्र जिवको नाश हुनु का साथै माटोको बनावट पनि बिग्रिने हुँदा तथा वातावरण प्रदुषण हुँदा उक्त समस्या समाधान गर्न यस बेलर मेशिनको प्रयोग गर्न सकिन्छ।
- यस मेशिनले कम्बाईन हार्भेष्टरले खेतमा छोडेको पराल वा नल आदि लाई जम्मा गरेर गोलो बण्डल (बण्डलको उचाई : ६४ से. मी. , बण्डलको व्यास : ६४ से. मी. र तौल : १६ के. जी.) बनाउने काम गर्दछ।
- यस मेशिनलाई डबल क्लच भएको २५ अश्वशक्ति वा सो भन्दा बढीको ४ पाँग्रे ट्रेक्टरको पि.टि.ओ. बाट संचालन गर्न सकिन्छ ।
- परालका बन्डलको अन्य विभिन्न क्षेत्रमा उपयोगिता रहेको हुनाले किसानले उक्त मेशिनबाट थप आम्दानी गर्न सक्नेछ ।
- गाईबस्तुको चारा, च्याउ खेती, प्याकेजिङ्ग, बायोग्याँस तथा बिधुत उत्पादनमा यस्ता परालका बन्डलको प्रयोग गर्न सकिन्छ ।
- यो मेशिन गहुँ, धान र कोदोको लागि उपयुक्त छ ।
- यस मेशिनको प्रभाबाकारीता धान भन्दा गहुँमा राम्रो रहेको छ ।

कार्यक्षमता

- खेतमा रहेको परालको मात्राको अधारमा प्रति घण्टा ३० देखि ४० वटा परालको बण्डल (परालको घनत्व, चिस्यानको मात्रा र कडापनको आधारमा) तयार गर्न सकिन्छ ।

उपयोगिता

- ग्रामिण सडक राम्रो भएको तराई तथा भित्रि मधेशको समतल भू-भागमा र कम्बाईन हार्भेष्टरको प्रयोग भईरहेको क्षेत्रमा सजिलै प्रयोग गर्न सकिन्छ ।

मुल्य ने.रु. ८,००,०००/- प्रति थान

नेपाल सरकार

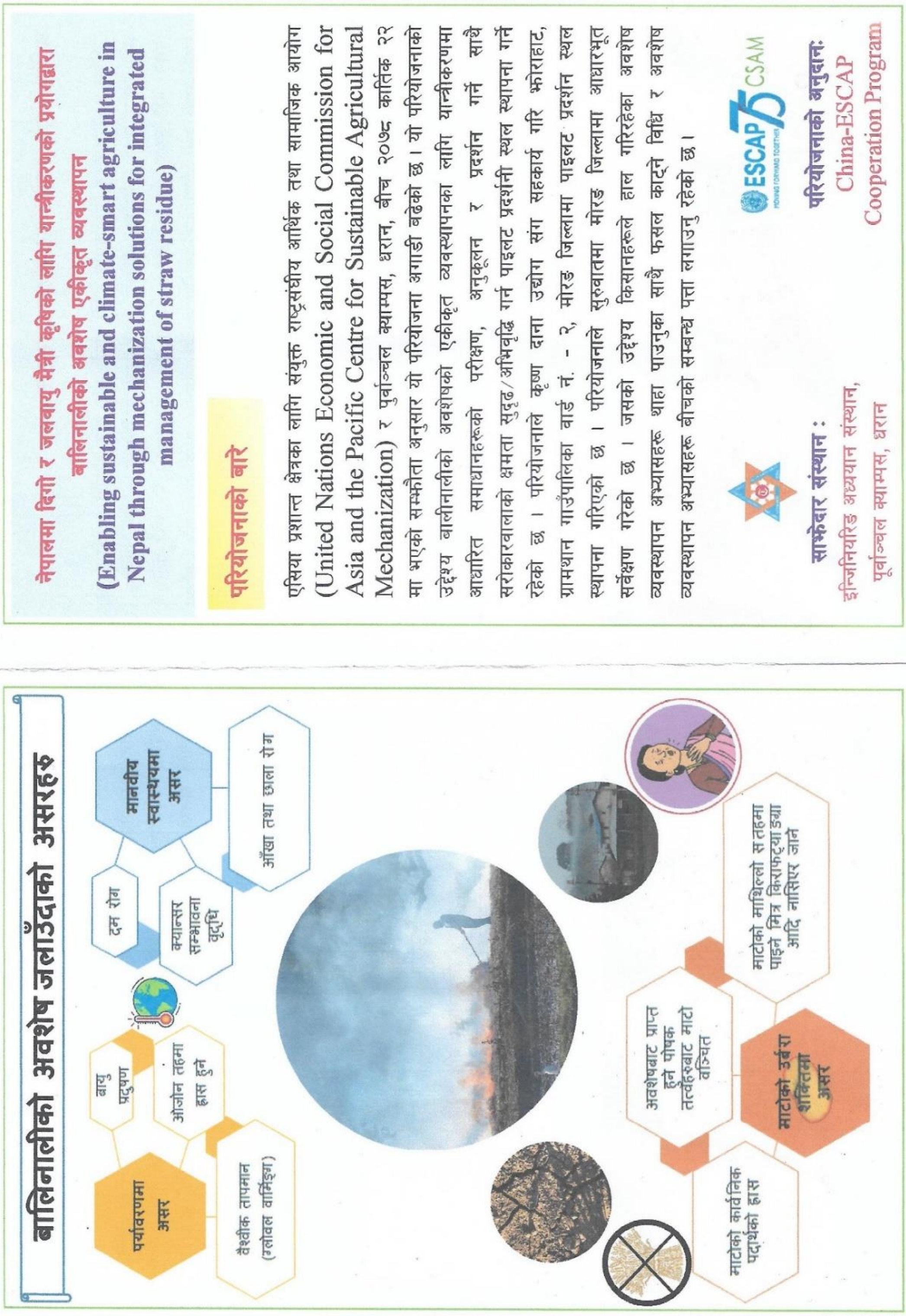
नेपाल कृषि अनुसन्धान परिषद्

कृषि औजार अनुसन्धान केन्द्र

रानीघाट, बीरगंज, पर्सा

Source: NARC, Agriculture Implement Research Station, Birgunj

Annex 11: Awareness leaflet (page 1) to stop open burning of crop residue, developed by Purwanchal Campus, IOE



Source: Purwanchal Campus, Institute of Engineering, Dharan, funded by China-ESCAP Cooperation Program through CSAM

Annex 12: Awareness leaflet (page 2) to stop open burning of crop residue, developed by Purwanchal Campus, IOE

बालिनालीको अवशेष जलाउँदाका असरहरु

विभिन्न बालीनालीहरु भित्र्याएपछि बाँकी रहेको डाँठ, दाँइ गरेपछि बचेको पराल, भुस, लहरा तथा जमीनमा असरल्ल पातहरुलाई बालीनाली अवशेष भनिन्छ । विगत केही समय देखि कृषिक्षेत्रमा बिषेश गरि कम्बाईण्ड हार्भेस्टरको प्रयोगले गर्दा, जसले ठूलो परिमाणमा अवशेष खेतमा छोड्दछ, हाल अवशेषको समुचित व्यवस्थापन एउटा चुनौतिको रुपमा रहेको छ । किसानहरु बिषेशत् अवशेष व्यवस्थापनमा थप खर्च र ज्यामी लाग्ने, अनि समयको अभाव र दुई वाली बिचको समय कमले गर्दा यसलाई जलाउन थालेको देखिन्छ ।

अवशेष जलाउँदा मुख्यतय ग्लोबल वार्मिङमा योगदान गर्ने हरितगृह ग्यासहरू (GHGs) उत्सर्जन, बायु प्रदुषणका कारणले गर्दा मानव तथा जीवजन्तुको स्वास्थ्यमा प्रभाव, पर्यावरण तथा जैविक बिबिधतामा हानि, माटोमा भएका सुक्ष्म उपयोगी जिवहरुको मृत्युले गर्दा माटोको पोषण र उर्बरतामा हानि, माथिको माटो कडा हुनाले भू-क्षय, इत्यादि समस्या निम्तने गर्दछ ।

कम्बाइन हार्भेस्टर प्रयोग गरेर धानबालि भित्र्याए पछि खेतमा रहेको अवशेष जलाउदै एक किसान (तस्बिर: सागर काफ्ले / पुर्वाचल क्याम्पस)

बालिनालीको अवशेषका उपयोगहरु

बालीनालीको अवशेषलाई मुख्यतय पशुको आहाराको रुपमा, खान पकाउने इन्धन तथा जैविक मलको रुपमा प्रयोग गर्दै आइएको छ । यस परियोजना बिषेशत् अवशेषको दुई तरिकाले प्रयोगको बारे कार्य गर्दैछ, एक धानकाटि सकेपछि खेतमा रहेको अवशेषलाई न्यून जोताई प्रविधिका कृषि यन्त्र (जस्तैः ह्यापी सिडर) प्रयोग गरेर माटोमै मिसाउने जसले गर्दा माटोमा जैविक पदार्थको मात्र बढ्नाले उर्बारा शक्ति बढ्दछ ।

त्यस्तै, अर्को तरिकामा धानको अवशेषलाई बेलरको प्रयोगद्वारा सङ्कलन गरेर, त्यसमा आवाश्यक अन्य पौष्टिक पदार्थ मिसाएर, सङ्कुचन यन्त्र (Compressor) को प्रयोग गरेर ईटा आकारको पशु फिड ब्लक बनाउने रहेको छ। यसरि ब्लक बनाउदा पौष्टिक तत्व बढाउन सकिने भएको हुँदा पशुको दुध तथा मासु उत्पादनमा बृद्धि हुनेछ, साथै ब्लक कम्ति ठाउँमा धेरै संचित गर्न सकिने हुँदा संचिती तथा ढुवानी खर्च कम हुन जान्छ ।

पशु फिड ब्लक

कम्बाइन हार्भेस्टर प्रयोग गरे पश्चात खेतमा छरिएको धानको अवशेष भेला पार्दै किसान दम्पति (तस्बिर: सागर काफ्ले / पुर्वाचल क्याम्पस)

Source: Purwanchal Campus, Institute of Engineering, Dharan, funded by China-ESCAP Cooperation Program through CSAM

Annex 13: Awareness leaflet (page 1) in the use of technology for crop residue management, developed by Purwanchal Campus, IOE

नेपालमा दिगो र जलवायु मैत्री कृषिको लागि यान्त्रीकरणको प्रयोगद्वारा बालिनालीको अवशेष एकीकृत व्यवस्थापन
(Enabling sustainable and climate-smart agriculture in Nepal through mechanization solutions for integrated management of straw residue)

एसिया प्रशान्त क्षेत्रका लागि संयुक्त राष्ट्रसंघीय आर्थिक तथा सामाजिक आयोग (United Nations Economic and Social Commission for Asia and the Pacific Centre for Sustainable Agricultural Mechanization) र पुर्वाञ्चल क्याम्पस, धरान, बीच २०७८ कार्तिक २२ मा भएको सम्झौता अनुसार यो परियोजना अगाडी बढेको छ। यो परियोजनाको उद्देश्य बालीनालीको अवशेषको एकीकृत व्यवस्थापनका लागि यान्त्रीकरणमा आधारित समाधानहरूको परीक्षण, अनुकूलन र प्रदर्शन गर्ने साथै सरोकारवालाको क्षमता सुदृढ/अभिवृद्धि गर्न पाइलट प्रदर्शनी स्थल स्थापना गर्ने रहेको छ । परियोजनाले कृष्ण दाना उद्योग संग सहकार्य गरि झोराहाट, ग्रामथान गाउँपालिका वार्ड नं. - २, मोरङ जिल्लामा पाइलट प्रदर्शन स्थल स्थापना गरिएको छ । परियोजनाले सुरुवातमा मोरङ जिल्लामा आधारभूत सर्वेक्षण गरेको छ । जसको उद्देश्य किसानहरूले हाल गरिरहेका अवशेष व्यवस्थापन अभ्यासहरू थाहा पाउनुका साथै फसल काट्ने विधि र अवशेष व्यवस्थापन अभ्यासहरू बीचको सम्बन्ध पत्ता लगाउनु रहेको छ ।

यो ब्रोसरमा यो परियोजना अन्तर्गत बालिनालिको अवशेष एकीकृत व्यवस्थापन गर्न प्रयोग गरिएका औजारहरुको बारे छोटो जानकारी पेस गरिएको छ ।

साझेदार संस्थान :
इन्जिनियरिङ अध्ययान संस्थान,
पूर्वाञ्चल क्याम्पस, धरान

ESCAP CSAM

परियोजनाको अनुदान:
China-ESCAP
Cooperation Program

स्ट्र (Straw) बेलर

धान तथा गहुको सिजनमा कम्बाइन हर्बेस्टरले दाउनी गर्दा पराल तथा भुस खेत बारिमा नै छाड्ने गरिन्छ, जसले गर्दा समयमा खनजोत गर्न अप्ठ्यारो पर्न जान्छ। तुरन्तै पराल हटाउन सकिएन भने अर्को सिजनको बाली लगाउन ढिलाई हुन्छ, जसले उत्पादनमा ठुलो असर पुर्याउछ । जसको फलस्वरुप किसानहरुले पराल जलाउने गर्दछन । यो समस्याको ब्याबस्थापना गर्नका लागि स्ट्र बेलरको निर्माण गरिएको छ, जसले परालालाई ढुवानी र भण्डारण गर्न योग्य बनाउछ । यसले परालालाई खदिलो गरी गोलाकार तथा आयाताकार आकारमा बाधने गर्दछ ।

यो बेलारलाई ट्र्याक्टरको पि टि वो (PTO) ले सन्चालन गर्दछ। यो मेसिन चलाऊनलाई ट्र्याक्टरको पावर ३५ हर्स पावर भन्दा माथि हुनु पर्छ । बेलार दुई प्रकारको पाईन्छ - आयाताकार र गोलाकार बेलार ।

स्ट्र ब्लक बनाउने मेसिन

यो बिधुतिय माध्ययमबाट चल्ने अर्ध स्वचालित हाइड्रोलिक मेसिन हो । ३ हर्स पावरको बिधुतिय मोटरको सहयताले हाइड्रोलिक पम्पलाई सन्चालन गरी सबै कार्यहरु सम्पन्न गर्दछायो मेसिनले मसिनो परालको टुक्राहरुलाई मेसिनको च्याम्बरमा कम्प्याक्ट गरी करिब करिब ४ देखी ५ के जि को ब्लक उत्पादन गर्ने गर्दछ । यो ब्लकलाई प्लस्टिकको बोरामा प्याकेजिङ गरी राख्न सकिन्छ, जसले गर्दा भण्डारण एबम ढुवानी गर्न सरल हुन जान्छ ।

पशु फिड ब्लक

स्ट्र ब्लक बनाउने मेसिन

Source: Purwanchal Campus, Institute of Engineering, Dharan, funded by China-ESCAP Cooperation Program through CSAM

Annex 14: Awareness leaflet (page 2) in the use of technology for crop residue management, developed by Purwanchal Campus, IOE

मल्चर

मल्चर मेसिनले खेतमा रहेको धानको लामा-लामा छवाली तथा अन्य बनस्पतीहरुलाई मसिनो बनाइ काटेर माटोमा मिसाउछ, जसले जमिनको चिसोपनालाई बचाएर राख्नमा मधत गर्दछ। यसले झारलाई नियन्त्रण, माटोको पोशण तत्व बचाउने, भूक्षयीकरणबाट बचाउने र बालिनालिमा लाग्ने रोगब्यादी बाट पनि बचाउँछ ।

सुपर सिडर र गहुँ खेतीमा यसको प्रयोगको फाइदा

सुपर सिडर यस्तो मेसिन हो, जसले एकै पटकमा खेतमा रहेको लामा लामा पराल तथा अन्य बनस्पतिहरुको अवशेस्लाई माटोमा मिलाई बिउ छर्ने काम गर्दछ। यस मेसिनको अघिल्लो भागमा रोटाभेटर रहेको हुन्छ जसलाई ट्रयाकटरको पि टी वो (PTO) शाफ्टले घुमाउने काम गर्दछ । रोटाभेटरले जोत्दा, रोटाभेटर भन्दा पछाडि रहेको ट्रेलिङ बोर्डमा जोडले माटोलाई फाल्ने हुँदा माटो मिहिन बन्दछ। ट्रेलिङ बोर्ड भन्दा पछाडि बिउ छर्ने भाग जडान गरिएको हुन्छ, जसले हामीले सेट गरे अनुसार मल र बिउ जमीनमा छर्ने काम गर्डछ । यस मेसिनले लगातार बिउ झार्ने किसिमको कुनै पनि बिउ रोप्न मिल्छ, जस्तै: गहु, छरुवा धान, घासको बिउ र दाल जन्य बिउहरु। कुनै पनि बिउ छर्दा यो मेसिनको क्यालिब्रेसन गर्नु पर्ने हुन्छ ।

क्यालिब्रेसन गर्नु भन्नाले कुनै पनि बिउको तोकिएको बिउ छर्ने दर लाई कायम गर्नु हो। जस्तै: गहुको बिउ छर्ने दर १२० के जी प्रति हेक्टर हो भने सुपर सिडरले १ हेक्टर जोत्दा १२० के जि नै बिउ झार्नु पर्छ ।

ड्रम सिडर र छरुवा धान प्रविधिको फाइदा

छरुवा धान प्रविधि एक श्रोत संरक्षण प्रविधि हो, यसले प्रयोगले श्रमिकको कम आवश्यकता पर्दछ जस्तै दुई जनाले ८ घण्टामा १ हेक्टर सम्म बीउ छर्न सक्छन् । यस प्रविधिको प्रयोगले ब्याड राख्ने, बेर्ना उखेल्ने र रोपाई गर्ने जस्तो बढी खर्च लाग्ने कार्यहरु गर्नु पर्दैन साथै गोडमेल गर्न पनि सजिलो हुन्छ । यो प्रविधिबाट धान खेती गर्दा रोपाई भन्दा १०-१५ प्रतिशत सम्म बढी उत्पादन लिन सकिन्छ ।

यस प्रविधिबाट धान लगाउँदा रोपेको भन्दा १०-१५ दिन अगाडी बाली पाक्छ र हिउँदे बाली समयमा लगाउन सकिन्छ । यसबाट करिब २५ प्रतिशत सम्म बीउको बचत हुन्छ र स्वस्थ बालीको विकास हुन्छ ।

कम्बाइन हार्भेस्टर

कम्बाइन हार्वेस्टर एक बहुमुखी मेसिन हो जसले विभिन्न प्रकारका अन्न बालीहरूलाई प्रभावकारी रूपमा काट्न, दाइं गर्न तथा अन्न सफा गर्ने कार्य गर्दछ । बिशेष गरि नेपालमा यसलाई धान, गहुँ तथा मकै बालीमा प्रयोग गरिन्छ । कम्बाइन हार्भेस्टर आर्थिक रूपमा सबैभन्दा महत्त्वपूर्ण श्रम-बचत गर्ने आविष्कार मध्ये एक हो, जसले कृषिमा संलग्न श्रमलाई उल्लेखनीय रूपमा घटाउँछ । बिशेषता प्रमुख तिन प्रकारका कम्बाइन हार्भेस्टरहरू हाल प्रयोगमा छन: आफ्नै इन्जिन भएको, बेल्ट सिस्टम भएको र ट्र्याक्टरमा माउन्ट गर्न पर्ने ।

आधुनिक कम्बाइन हार्वेस्टर सामान्यतया मेसिनको सबै कार्यहरु संचालन गर्नका लागि शक्ति उत्पन्न गर्न डिजेल इन्जिन हुन्छ। एक सामान्य इन्जिनमा छ देखि आठ सिलिन्डरहरू हुन्छन् जसको २००-४०० हर्स पावर हुने गर्छ ।

Source: Purwanchal Campus, Institute of Engineering, Dharan, funded by China-ESCAP Cooperation Program through CSAM