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RESEARCH ARTICLE

# SOIL ORGANIC MATTER (SOM): STATUS, TARGET AND CHALLENGES IN NEPAL

**J.J. Gairhe[a]*, S. Khanal[a] and S. Thapa[b]**

*[a]Paklihawa Campus, Institute of Agriculture and Animal Science*
*[b]PG Program, Institute of Agriculture and Animal Science*
**Corresponding Author e-mail: janma@iaas.edu.np, janmajaya@gmail.com*



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**ABSTRACT**

Changes in soil organic matter (SOM) are slow and difficult to monitor, usually apparent after few decades. Recent changes in the agriculture had its influence on soil, including the soil organic matter content. About 60% of soil in Nepal now have low organic matter content. Agriculture Perspective Plan (APP) was focused more on the concept of green revolution to increase the chemical fertilizer inputs, however, the scenario is changing. Use of organic fertilizers is promoted extensively by government and different organizations with a target of increasing SOM content from 1.92% in 2015 to 4% by 2035. This paper aims at analysing the current status, targeted goal and the challenges faced in the augmentation of the soil organic matter using data available. Achieving this target requires an addition of extra 2.244 ton/ha of organic matter on a yearly basis for 20 years. The average amount of organic matter (2.5-3 ton/ha) applied is lesser than a single season grain harvest. 4.69% of sites had high soil organic matter in fiscal year 075/76 which slipped to 2.64% in 2076/77. The sites with low soil organic matter increased from 12.73% to 15.31%. The causes behind the SOM decline varies according to different agro-ecological zones like soil erosion, residue burning, imbalanced fertilizer use, defective FYM production etc. Findings suggest precise technologies required to be adopted to tackle with the different niche specific causes of soil fertility decline. Despite the complete nutrient content, bulky nature of organic fertilizers sets a major drawback regarding their transportation, distribution and commercialization. Government of Nepal is promoting organic fertilizer use by subsidizing their production cost by 50%. Following integrated nutrient management (INM) techniques, sustainable soil management practices (SSMP) and promotion of use of locally available resources can play a huge role in making the technology sustainable to the farmers.

**KEYWORDS**

Soil organic carbon, soil health, food security

## 1. Introduction

Organic matter, the living fraction of the soil, is considered as the heart of a healthy soil. Soil with adequate organic matter implies better soil structure, aggregate stability, bulk density, water holding capacity, nutrient cycling, cation exchange capacity, buffering capacity and much more (Murphy, 2015). The effects of soil organic matter (SOM) on the complex of soil properties is extensive and is usually subsumed under the term 'soil fertility'. Soil contains three times more carbon (C) than in atmosphere and 3.8 times more C than in biotic pool (Shrestha et al., 2008). Agricultural soil generally has organic matter between 3 to 6% (Berns and Knicker, 2014).

Providing food and fibre for a growing population in 21st century is no less than a challenge. Modern farming practice have a considerable impact on soil. Three to four crops are harvested annually in rotation from a single piece of land (Deshar, 2013; Raut et al., 2010; Dahal and Bajracharya, 2013). For centuries, subsistence form of Nepalese agriculture used organic fertilizer as the only source of nutrients. This scenario changed post the introduction of chemical fertilizers in 1960s. These fertilizers rapidly gained popularity accounting to their less bulky nature, transportability, ease of application and most importantly, the dramatic increase in yield. As the sales of chemical fertilizers escalated at the rate of 882.43 MT per annum in between 1991/92 to 2015/16, the traditionally used organic fertilizers were given less emphasis (Pandey et al., 2017).

Mostly centred on the use of technology based on green revolution, the Agriculture perspective plan (APP) (1995-2015) was focused more on the use of chemical fertilizers to rapidly increase production. It emphasized more on input and output rather than outcomes and impacts. Chemical fertilizer and irrigation were considered to be the main source of agricultural growth, somewhat like green revolution (PPTA, 2012). Aimed to increase the chemical fertilizer use with an average increment of 26000 metric ton per year, organic fertilizers seem to have received less attention. Changes in SOM are difficult to monitor, often becoming evident after few decades (Basnet, 1999). Slow decrease in soil organic matter has led us to this point, where apparently 60% of the soil in Nepal have low organic matter content (Kharal et al., 2018; SSD, 2016).

The nutrient available to the plant depends upon the soil properties (MOAC, 2000). Organic matter increases the water and nutrient retention capacity of soil (SoCo, 2009). However, decline in the SOM content leads to reduced cation exchange (CEC) and water holding capacity, resulting in a reduction in nutrient retention and supply capacity of the soil (Kimetu et al., 2008). Nutrient deficiency resulting from the deficiency of the organic matter cannot be restored by increased application of chemical fertilizers,

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especially in the humid tropics, where low activity clay have the limited ability to retain nutrients. The readily available nutrients applied to the soil will instantly be leached, causing decrease in the crop use efficiency of chemical fertilizer accordingly (Parr and Colacicco, 1987). This could be the one reason for the productivity of major food crop to be almost constant since the last three decades (Rijal, 2000). Government has put forward Agriculture development strategy (ADS) which has a target to increase the soil organic matter 1.96% in 2015 to 4% by 2035, which is a rather ambitious target. Different factors play an important role in SOM content variation throughout different parts of Nepal. As an important component for maintaining soil health, SOM needs to be closely studied. This paper attempts to analyse the past, present and future of SOM in Nepal. Various researches in the past have mentioned different factors influencing the SOM content from their respective fields. These available data are compiled and analysed with a goal of sustainable increase in SOM content. In these contexts, this paper attempts to explore the status of soil organic matter in Nepal along with the target set and challenges to achieve it.

## 2. Materials and Methods

This article is based on secondary information collected from the findings of different research articles, review papers, reports, books and conference proceedings. The collected information was subsequently reviewed and synthesized into the present form. Moreover, paired sample t test was used to test the significance between the longitudinal data. The processed data were presented in tables and graphs.

## 3. Results and Discussion

### 3.1 Status and target of soil organic matter in Nepal

In Nepalese condition, it is estimated that average quantity of nutrients removed by cereal crops annually approximates to 310 kg per hectare (Ghimire, 2009). However, the current fertilizer use trend in Nepal is 41 kg per hectare (Katyal and Reddy, 2020). The huge gap between nutrient uptake by plant and supplied by the soil creates a negative nutrient balance (MOAD, 2015). These nutrients are extracted by crops from the soil indigenous nutrient supply. Rapid removal of nutrients from soil without sufficient replenishment slowly strips the soil, making it infertile in long run. 60% of soil in Nepal are said to have low organic matter, 23% have low phosphorus, 18% have low potassium and 67% of soil are acidic (Mandal et al., 2004).

The forest soil had the highest SOC percentage (0.95%), followed by Bari (0.74%), Khet (0.65%) and degraded land (0.52%) in Chure region of Nepal. Moreover, the total The total SOC stock in the same study followed the order as Forest > Bari > Khet > Degraded land with the total SOC stock each land use being 110.0 t $ha^{-1}$, 96.5 t $ha^{-1}$, 86.8 t $ha^{-1}$ and 72.0 t $ha^{-1}$ respectively. The lower SOC content in Khet and Bari soil probably reflects continuous cultivation with minimum addition of SOM and sandy textured soil. Improvement of SOC percentage and soil quality maintenance is an important intervention to increase SOC storage capacity.

Reported that out of 5718 samples tested in fiscal year 2070/71, 44.47% contained low, 40.89% contained medium and 14.64% contained high organic matter (figure 1) (Dawadi and Thapa, 2015). The amount of organic matter differed as per different developmental regions, SOM content of eastern and far western region was found to be the lowest while it was highest at central.

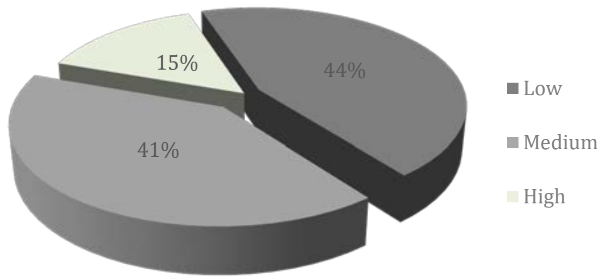


**Figure 1:** Status of soil organic matter in FY 2070/71 (2013/14) (Source: Dawadi & Thapa [19])

Based on the soil samples analysed by soil laboratory located at soil management directorate and regional soil laboratories located at various locations, it was found that soil samples with low soil organic matter declined by 0.04 units per year from fiscal year 071/72 to 074/75. Moreover, there was decline in soil samples with medium and high organic matters by 0.0228 and 0.0238 units per year during the same period (figure 2).

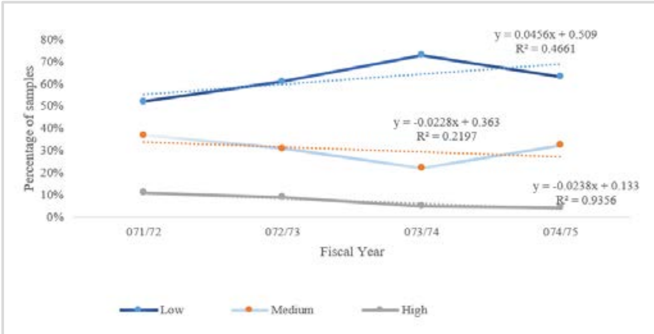


**Figure 2:** Status of soil organic carbon on samples studied by various soil labs of Nepal

Soil management directorate conducted 18 mobile soil campaign, regional soil test lab (RSTL) at Jhumka, Hetauda, Pokhara and Sundarpur conducted each of 10 mobile soil campaign and RSTL, Khajura conducted 14 such campaigns. The result of those campaigns is shown in table 1. Total of 73.05% of samples showed low organic matter, 24.67% samples contained medium organic matter and only 2.28% were with high organic matter.

**Table 1:** Status of soil organic matter obtained in mobile soil test campaign in Nepal conducted by various laboratories for fiscal year 074/75

| | Soil Management Directorate | Mobile soil test campaign by Regional laboratory | | | | Total |
|---|---|---|---|---|---|---|
| | | Jhumka | Hetauda | Pokhara | Sundarpur | |
| Low | 597(83.61) | 231(61.43) | 848(81.61) | 971(76.51) | 474(54.24) | 3121(73.05) |
| Medium | 79(11.06) | 131(34.84) | 186(17.90) | 283(22.3) | 375(42.9) | 1054(24.67) |
| High | 38(5.32) | 14(3.72) | 5(0.49) | 15(1.19) | 25(2.86) | 97(2.28) |
| Total | 714 | 376 | 1039 | 1269 | 874 | 4272 |

Note: Figure in the parenthesis includes percentage (Source: Dawadi and Thapa [19])

**Table 2:** Status of soil organic matter obtained in soil laboratories of Nepal for fiscal year 074/75.

| Soil organic matter | Soil management directorate | Regional Soil lab | | | | | Soil lab Surunga | Total |
|---|---|---|---|---|---|---|---|---|
| | | Jhumka | Hetauda | Pokhara | Khajura | Sundarpur | | |
| Low | 224 (37.96) | 291 (45.25) | 485 (71.85) | 167 (39.66) | 194 (46.63) | 181 (52.61) | 84 (55.26) | 1626 (50.17) |
| Medium | 295 (50) | 291 (45.25) | 173 (25.62) | 219 (52.01) | 212 (50.96) | 126 (36.63) | 62 (40.79) | 1378 (42.52) |
| High | 71 (12.34) | 61 (9.5) | 17 (2.53) | 35 (8.33) | 10 (2.41) | 37 (10.76) | 6 (3.95) | 237 (7.31) |
| | 590 | 643 | 675 | 421 | 416 | 344 | 152 | 3241 |

Note: Figure in the parenthesis includes percentage (Source: Dawadi and Thapa [19])

Various laboratories conducted 16316 tests from 3300 samples obtained from farmers, former DADO, students and various organizations. The interested farmers were found to increase within these years though they account only 10-15% of beneficiaries. Out of such analysed soil samples, 50.17% were with low organic matter, 42.52% were with medium level of organic matter and 7.31% were with high organic matter. Detail is shown in table 2.

Organic fertilizers have an upper hand over inorganic fertilizers in terms of complete nutrient content and longer availability of those nutrients (Khadka, 2016) reported the nutrient availability to plant to be positively correlated with soil organic matter content as it improves the soil properties. As reported by (Magdoff, 2000), crop yield increased by up to 12% per increase in 1% of soil organic matter. Depletion of organic matter has been recognized as one of the challenges for agriculture of Nepal in both hill and terai region. At present, organic matter usage by farmer approximates around 2.5-3 ton/ha. This amount is relatively more in hilly region as compared to terai region in spite of the higher cropping intensity in terai.

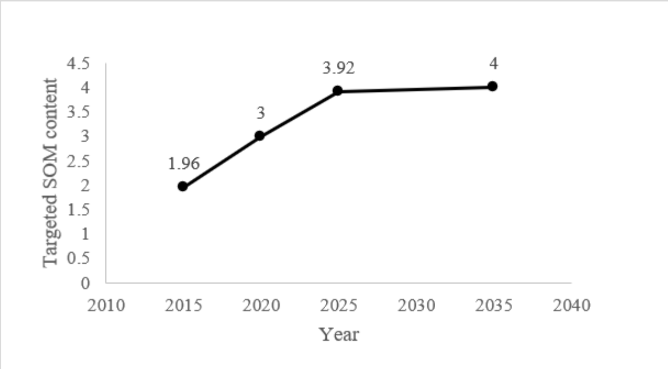


**Figure 3:** Target set by ADS for increase in soil organic matter in Nepal

Importance of organic matter in sustainability of food production is realized by Agriculture development strategy (ADS) which has a target to increase the soil organic matter 1.96% in 2015 to 4% by 2035. If we consider a hectare furrow slice of area (approximately 2,200 ton of soil), increasing the organic matter content by one percent requires addition of an extra 22 ton of organic matter over the crops nutritional requirement. Now, for increasing SOM from 1.92% to 4%, we require 44.88 ton per hectare (2.04% of 2,200 ton) increase in the SOM. If done on a yearly basis, an additional 2.244 ton per hectare of organic matter needs to be added over the crops nutritional requirement each year. This figure nearly approaches the current organic fertilizer usage by farmers. A rough evaluation of this amount can be made by the fact that grain harvest from the rice fields alone exceeds the total organic matter input (Tripathi et al., 2018).

Though, the ADS has targeted an increase of 4% in soil organic matter, but the scenario of achieving it is not conducive. Upon analysis of soil organic matter of Bagmati Province, significant decrease ($p<0.001$) was observed when comparing between fiscal year 2075/76 and 2076/77 (table 1). 4.69% of sites had high soil organic matter in fiscal year 075/76 which slipped to 2.64% in 2076/77. Moreover, the sites with low soil organic matter increased from 12.73% to 15.31%. Detail is shown in table 3. The detail of status on soil organic matter is shown in appendix 1.

**Table 3:** Ratings of soil organic matter in Bagmati Province in fiscal year 2075/76 and 2076/77.

| | 075/76 | 076/77 |
|---|---|---|
| High | 28(4.69) | 14(2.64) |
| Medium | 169(28.31) | 260(49.14) |
| Low | 324(54.27) | 174(32.89) |
| Very low | 76(12.73) | 81(15.31) |
| Total | 597(100) | 529(100) |
| P value | ***(t= -9.56) | |

Note: ***=P<0.001

Source: Annual reports (2075/76 & 2076/77, Provincial Soil & Fertilizer lab, Hetauda, Bagmati Province, Nepal.

### 3.2 Challenges in increasing soil organic matter in Nepal

Organic matter affects soil structure (aggregation), drainage, aeration (gas exchange properties), water holding capacity, pH, compaction and overall plant growth. The maintenance of adequate supply of organic matter is important in productive agriculture. An ideal conditioned soil contains 5% of organic matter. The historic loss of C from the SOM pool between the 1850s and 2000 is estimated at 78 ± 12 Gt compared with the emission of 270 ± 30 Gt from fossil fuel combustion. Despite its numerous direct and ancillary benefits, enhancing the SOM pool is a major challenge, especially in impoverished and depleted soils in harsh tropical climates. Increasing soil organic matter in Nepal is cumbersome task. The organic matter in soil is comparatively low in Nepal. In our context, soil organic matter is lost very quickly due to erosion, residue burning, lack of organic manure and poor farming techniques.

Crop residue play an important role in maintaining soil organic matter as well as improving the physical, chemical and biological properties of soil. Huge amount of nutrient is removed from the soil with crop residue removal. About 19.41 million metric tons of agriculture residue is produced in Nepal annually. These residues are produced mostly from terai region of Nepal (60%), followed by hill (35%) and mountain region (5%) respectively (WECS, 2010). Rice accounts for about 58% of this residue. In a rice-wheat cropping system, a total of 7-10 ton of residue is produced each year (Mandal et al., 2004). This residue is used as fuel for cooking, ruminant fodder, bedding material and raw materials in industries. About 10 ton of crop can remove 730kg NPK per hectare that is returned back to the soil in very little amount. In many districts of Nepal, the crop residue is burnt, instead of incorporation or being removed. This burning can lead up to 80% loss of N, 25% of P, 21% of K and 4-60% loss of S (Bisen and Rahangdale, 2017; Dobermann and Fairhurst, 2002). Reported the nutrient loss of over 35000 Mt of carbon, 571Mt of Nitrogen, 40Mt of phosphorus, 254 Mt of Potash and 38 Mt of sulphur from three districts of western terai in year 2013/14 due to residue burning. In the long run, removal of the straw causes reduction in soil nutrients like K, S, Zn, and Si. Residue burning reduces the loss of K as compared to completely removing residue. It converts straw into a source of mineral K (Dobermann and Fairhurst, 2002). The concept of crop residue removal has been described in terms of biomass energy input and output by (Rijal et al., 1991), highlighting the competing usage of animal dung between manure and fuel, agricultural residue between fuel and fodder. According to Sherchan and Karki even 10 ton $ha^{-1}$ of farmyard manure is not enough to maintain nutrient balance under rice-wheat rotation system (Sherchan and Karki, 2006).

Organic matter depletion not only puts question on the sustainability of current biomass production but also the food security of increasing population. Schreier et al. attested decrease of soil organic matter to be one of the cause for soil fertility decline (Schreier et al., 1994). The organic matter decline is not merely restricted to agricultural land but also prevalent in forest areas where an increasing amount of litter is removed and applied to agricultural land.

Many studies have time and again emphasized on the fact that the farm yard manure is the primary source of organic matter content in Nepalese soil. However, it is defectively prepared. Manure is left openly in field for several months in small heaps before finally being incorporated into the soil, causing a huge amount of nutrient loss through leaching and volatilization. This practice can lead to an approximate loss of 50% N and 90% K, especially in the rainy season. Manures are not properly decomposed before being incorporated leading to high C/N ratio and poor quality of FYM (Shrestha, 2009). Urine is another important source of nutrient containing about 1% N and 1.35% K, which is highly underutilized, most of this N is lost through volatilization (Amgai et al., 2018).

Traditional farming included a balanced integration between crops and livestock in a single management structure. Thus, a recycling of nutrient occurred between these two systems, providing FYM for crops and forage for animals. However, the shift from traditional farming has Pilbeam et al. reports that the breakdown in the linkage between forest, livestock and cropping system is affecting the soil fertility (Pilbeam et al., 2005).

Land abandonment has drastically increased over the past few decades. Current exodus to foreign countries and urban areas for employment has a considerable effect in the population demographics. As a result, soil in less populated areas were found to be less fertile due to less livestock and consequently less manure (Jaquet et al., 2015). Requiring three person months activity per year, production of FYM is quite a time-consuming and laborious process; thus, lack of availability of labour can affecting the production of FYM.

Topographical structure of Nepal accounts for erosion of a huge amount of top soil (Shrestha et al., 2008). Soil organic matter is mostly concentrated in the top 30 cm of the mineral soil horizon; consequently, they are lost along with the top soil (Sitaula et al., 2004). A single inch of soil requires 500-1000 years to form but can be destroyed in a short and single rain event. Every year about 336 million tons of soil are carried from the main river system to India (Acharya and Kafle, 2009). Agricultural land is mainly prone to surface soil erosion, ranging from 2 ton/ha to 105 ton/ha of soil eroded annually. Five ton/ha of soil loss equates to 75 kg/ha of organic matter, 8 kg/ha of nitrogen, 10kg/ha of potassium and 5 kg/ha of phosphorus loss (Tripathi, 2009).

Organic matter in cultivated soil is much lesser as compared to other land use system. Rapid mineralization due to tillage, insufficient addition, crop residue removal and lack of crop rotation might be the reason behind it (Chauhan et al., 2014). High temperature in terai region makes the situation worse by facilitating a rapid organic matter mineralization.

Owing to the subsidies, farmers in Nepal have a general tendency of applying the acid forming nitrogenous fertilizers like urea only. This prevalence of imbalanced use of these fertilizer causes the soil degradation. Organic matter can be used in reclamation of acidic soil, as it is considered to be as good as lime in terms of its capacity to buffer soil acidity.

### 3.3 Initiatives for amelioration

Government is promoting vermi-culture technology, cattle shed improvement program, organic fertilizer production plant establishment program and subsidy on purchase of organic fertilizers. Reducing deforestation, promoting integrated soil and plant nutrient management, integrated crop nutrition, crop residue use etc. are some of the strategies made for achieving these targets.

Subsidy on organic fertilizer was started in 2011 by Ministry of Agricultural Development with the promulgation of organic fertilizer subsidy guideline for promoting the use of organic fertilizers and maintain soil health (Bista et al., 2018). Government provided 50% subsidy on cost of production of 5000 Mt of organic fertilizer. Organic fertilizer grant procedure (2019) subsidizes 50 percent or NRs10 per kg on organic fertilizer (Henderson et al., 2016; MOALD, 2019).

Bishwakarma et al. reported an increase in SOM from 3.3% to 3.8% by just improvement of management and quality of FYM (Bishwakarma et al., 2015; Shrestha et al., 2014). Improved heap or pit method of FYM preparation, along with improved cattle shed management helps to reduce the nutrient loss from manure pits. Manures prepared with improved method provides 2-3 times more nutrients than the ordinary manure and supports better crop yield. About 90 percent of the nutrient loss from the soil due to crop harvest could be recovered through incorporation of 30 percent of crop residue back to the soil (Bista et al., 2014).

Even if we have a good market, the lack of raw materials and bulky nature can make the availability of commercial organic fertilizers difficult. Thus, it is important to promote organic fertilizers at local level. Pilbeam et al. reported the farmers to prefer chemical fertilizer as to FYM due to the ease of transport and application, disregarding the detrimental hardening of soil.

Farmers have low technical knowledge and resource constraints to adoption of a rational management option. The application rates are more affected by the availability than by the clear understanding of balanced crop nutrition and concept of soil fertility. Subsistence agriculture is a way of life in Nepal with less than 0.8 hectare of average landholding per family (Shrestha, 2011). Given the circumstances, high input commercial agriculture seems out of question. It is important to consider the usage of locally available resources for SOM management.

Interest in the soil organic matter has hyped due to soil organic carbon. This carbon build-up in the form of $CO_2$ is responsible for global warming. Soil contains more carbon stored in it than both vegetation and atmosphere combined. Each percent of the soil organic matter in the top 6 inches of soil contains same amount of carbon as in the atmosphere directly over the field. Therefore, the amount of carbon-dioxide in atmosphere doubles per percentage decrease in the soil organic matter. Various human activities are responsible for converting the soil organic carbon to carbon dioxide.

## 4. Conclusions

Increasing the productivity for feeding the ever-increasing world population is a major challenge in recent times. Sustainable maintenance of productivity can be achieved only with minimal or zero adverse impact to the environment. Soil organic matter plays an important role in soil sustainability. Sole use of organic fertilizer might be an option to solve the organic matter decline, however, the extent of its applicability is a question, considering the quantity of food required to be produced. An integration of organic matter with inorganic nutrient is a must. Application of inorganic fertilizers in a nutrient deficient soil increases the plant available nutrients, crop production and consequently, the plant residue.

The major contributors of organic matter decline might vary according to different agro-ecological zones. Thus, the management strategies must vary accordingly, with the niche specific cause identification. Site-specific technologies should be identified according to the soils, climate, cropping and farming systems to create a positive nutrient balance system.

Adoption of these technologies at farmers' level seem to be lacking. Lack of awareness, decreased landholding, labour shortage etc. may be amongst the few causes behind it. It is necessary that the future researches be focused on making these technologies more farmer-friendly and adaptable at local condition. Extension work should be made more effective for small holder farmers. Amelioration the present SOM to the targeted level requires a collective effort from all the stakeholders.

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