Soil Fertility Management and Agricultural Production Issues with Reference to the Middle Mountain Regions of Nepal

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1. INTRODUCTION

To achieve an increase in food production, the Government in the past 35 years has established a nationwide network and infrastructures for agricultural research, extension/education, farm irrigation, farm credit and marketing institutions. Through these agencies, attempts were made to develop, introduce, extend and market seeds of high yielding crop varieties, fertilizers, agrochemicals and agricultural tools.

Despite these attempts, food grain production only increased from 3,152,000 metric tons in 1961/62 to 5,690,000 metric tons in 1989/90. The average annual production increases are 2.1 %, and this rate does not even keep pace with the population growth rate over the same period. This modest increase in food production was attributed mainly to the expansion in agricultural land rather than as a result of an increase in productivity or the use of agricultural inputs and technologies (Eighth Five Year Plan, 1992). The static or declining productivity for most of the major crops (Figure 1) is also an indication of the inadequacy of the development efforts which in many cases were unable to maintain previous levels of production. The problem is more acute in the Hill and Mountain regions (Figure 2) where the yields of main food crops have declined. From the point of view of crop productivity and environmental stability, the development efforts over the recent past are not at all impressive.

Realizing this fact, the eighth 5-year plan which is currently underway has shifted policy emphasis away from merely "increased food production", towards "increased integrated agricultural production which is in harmony with ecological and environmental conditions and which fosters efficient institutional services and sound management". The result from this shift is yet to be seen.

There are various reasons for the stagnation or decline of crop productivity. Low and declining soil fertility has been recognized as the most crucial problem (Pradhan et al., 1992; Hobbs and Giri, 1992; Pandey, 1991; World Bank, 1990; Joshy and Deo, 1976). The indiscriminate encroachment of agriculture into the forest as well as the expansion onto steeply sloping lands has resulted in irreparable losses of soils and natural vegetation causing severe land and environmental degradation. This, together with continuous soil mining through the use of high yielding varieties, intensive multiple cropping systems and inadequate and imbalanced fertilization further contributed to soil fertility and crop productivity declines. Increased population pressure is no doubt the root of the problem.

Since there is no or little scope for expanding cultivable land, additional food which is needed to feed the growing population has to come from increased yields from the existing land area. The yields could be increased by raising cropping intensity, extending irrigated areas and growing high yielding varieties but this would result in further depletion of soil fertility if the removed nutrients taken up by the plants are not replenished. Therefore, management of soil fertility and plant nutrition is the key factor to sustaining agricultural productivity and environmental stability. In this paper, some of the key issues in soil fertility management and agricultural production pertinent to the middle mountains region will be discussed.

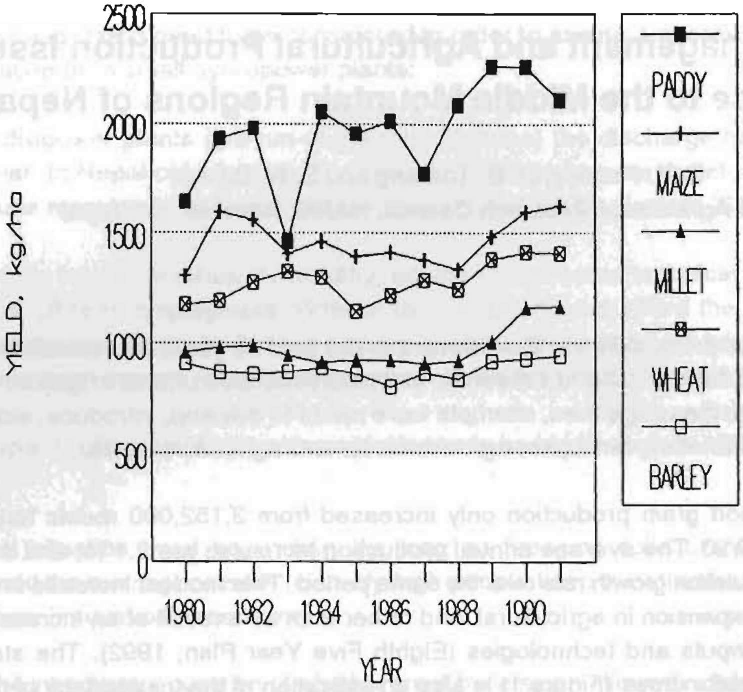

Figure 1. Food crops productivity trend, Nepal.

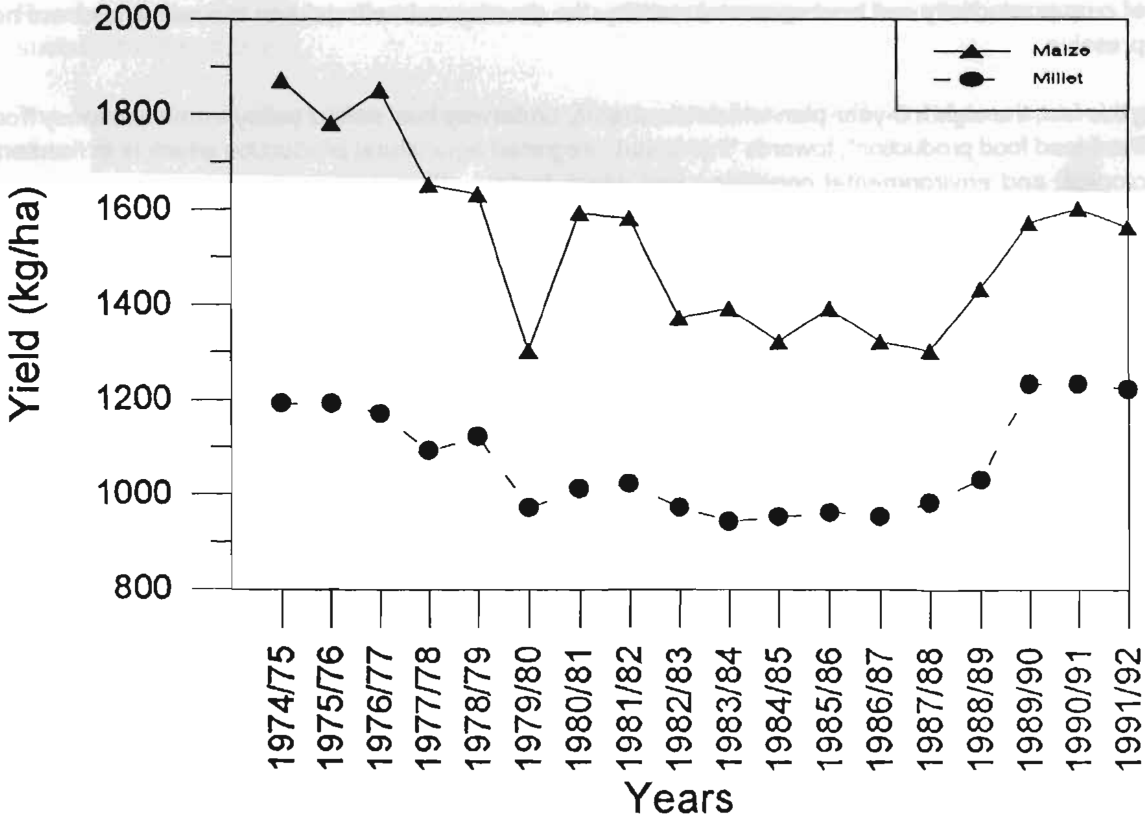

Figure 2. Maize and millet production trends in Nepal Mid Hills.

2. SOILS OF THE MIDDLE MOUNTAIN REGIONS

The middle mountain region, which occupies about 30 percent of the total land of the country, is the homeland of 45 % of the total population (approximately 19 million, based on the 1991 population census). The region has a very complex topography, elevation, geology and vegetation; hence the soils in this region are also diverse.

The LRMP has identified 4 different land systems in this region and these are further sub-divided into 7 Land Units (LRMP Land Systems report, 1986). The river valleys, which are the grain basket of this region, have alluvial soils of different texture and depth classes. These valleys are intensively cultivated with 2-3 crops a year where irrigation is available. The main cropping sequences in the low land cultivation system are rice - rice - wheat, rice - wheat - maize, or rice - wheat and rice - potato. The elevated terraces (*Tars*), which are formed by the erosional deposition, have mostly neutral to acidic red soils and are generally cultivated with upland crops such as maize, millet, upland paddy etc. However, if irrigation water is made available, rice-based cropping systems are followed. In general, the soils derived from granite are sandy, from shale, silty and from limestone, clayey.

The soils of this region are generally slightly acidic to acidic in reaction, and the organic matter content is in the medium range. In terms of nutrient content, the nitrogen and available phosphorus are low to medium, and the availability of potassium is medium to high.

3. TRADITIONAL SOIL FERTILITY MANAGEMENT PRACTICES

Almost all farmers in Nepal have traditionally followed integrated soil fertility management practices throughout time and these practices are built into the indigenous methods of farm management. For example, terracing, slicing the walls of terrace riser, bringing flood water into the field, leaf and in-situ green manuring, application of organic manures (FYM, compost, oil cakes, bone-meal etc.), shifting herds for in-situ terrace manuring and inclusion of various legumes in crop rotations are all in-built agronomical practices that supply plant nutrients to the field. Similarly, there are a number of other indigenous soil and nutrient management practices that are followed in different cropping systems and based on local conditions and resources.

Over the time, it was felt that these technologies alone were insufficient to meet the production demands for food required to sustain the increased population. Therefore, chemical fertilizer was brought into the farming system and this is a relatively recent introduction to most Nepalese farmers. Farmers have accepted fertilizers into their system but for various reasons, most of them use fertilizers only as a supplement to their indigenous resources. Nevertheless, its use is increasing and is becoming an essential input into the farming system. The biggest problem is the availability of both organic and inorganic nutrients and its transport to the fields.

An analysis of the present situation reveals that Nepal's future food security will not be passing without crisis if measures to cope with the declining soil fertility are not taken seriously. Combinations of all possible sources of nutrients are needed to arrive at an "Integrated Plant Nutrients System" that is appropriate for sustainable agricultural development.

4. FERTILIZER USE

The 1992/93 fertilizer consumption reached a level of 75,099 metric tons of nutrients with an average consumption of only 25 kg NPK fertilizer nutrients per hectare per annum. Of the total fertilizer distribution, 62% was in the Terai, 36% in the hills and 2% in the mountain regions (Figure 3). Fertilizer use in the hills and mountain regions is low due to inadequate institutional services, poor transport infrastructures and farmers' low buying capacity.

There is no doubt that fertilizer has raised the crop productivity in agriculture. However, there is a growing resistance to its use due to the high cost and increased concern about environmental hazards. Two years ago, the government lifted a major portion of the subsidy on most of the fertilizer materials except urea. This caused stagnation in fertilizer use last year and may further cut down its use in the coming years. This may accelerate the nutrient imbalance problem in the soil and will result in reduced productivity.

A blanket dose of 100:60:40 kg/ha of N, P_2O_5 and K_2O were recommended for high yielding varieties and 60:40:30 kg/ha for local varieties in the 1960's. In the 1970's, these fertilizer recommendations were revised, and extrapolated to individual districts on the basis of accumulated experimental results and soil survey data (Joshy and Deo, 1976). However, those recommendations were based mainly on work conducted in the Terai having thus a limited use for hill conditions.

The HMG/N in cooperation with FAO implemented a Project called "Increased Food Production and Farmers' Income in the Hills through Fertilizer and Related Inputs". During its campaign between 1983/84-89/90, the project conducted around 3332 fertilizer verification trials on the main food crops (rice, wheat, maize and potato) in 22 hill districts in the Eastern, Central and Western Developmental Regions. The results have been comprehensively analyzed and documented in Project's Field Documents No 1, 2, 3 (Jensen, 1987), 5, 6,7 and 8 (Pandey, 1991) for rice, wheat, maize and potato crops and are also available in a computer data bank at the Soil Science Division. Based on all the soil tests, crops responded well to nitrogen, moderately well to phosphate and there was only a slight to moderate response to potash (Pandey, 1991).

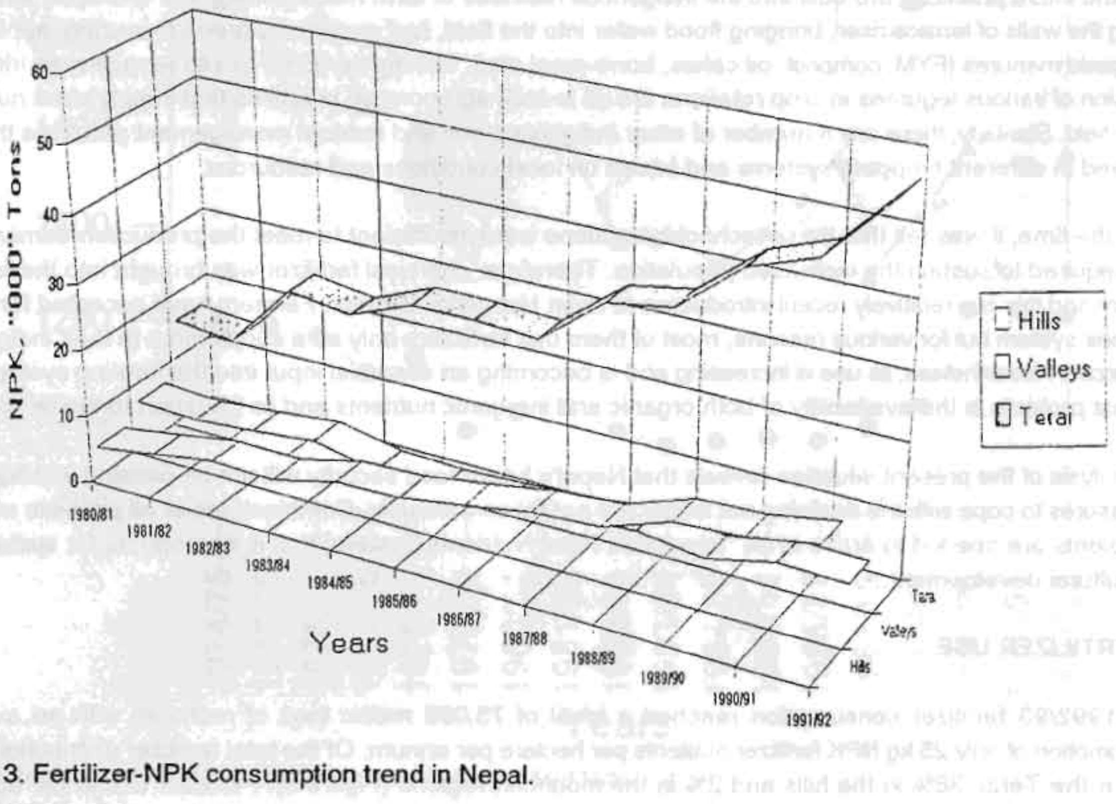

Figure 3. Fertilizer-NPK consumption trend in Nepal.

Based on these findings, the optimum plant nutrient recommendations for farmers with and without resource constraints were computed as shown in Table 1.

Table 1. Plant nutrient recommendations (kg/ha), Guidelines for resource constrained and non-constrained farmers, computed at national level.

	Farmers with Resource Constraints					Farmers without Resource Constraints				
Crop	N	P2O5	K2O	Net Return Rs/ha	VCR	N	P2O5	K2O	Net Return Rs/ha	VCR
Rice	70	40	30	4,596	5.64	140	40	30	5,737	4.59
Wheat	60	40	30	3,763	4.75	120	40	30	5,038	4.31
Maize	60	45	30	4,012	5.00	120	45	30	5,369	4.51
Potato	45	30	60	10,414	13.09	90	30	60	15,682	13.53

The nitrogen, phosphate and potassium recommendations were also calculated for each district for which the response function curves are available for each of four crops. The project also carried out more than 2600 fertilizer demonstrations on rice, wheat, maize and potato crops in 23 hill districts.

An economic analysis of these fertilizer trials and demonstrations confirmed that the use of mineral fertilizer is a viable means of increasing crop production and farmers' income even in the hill areas of Nepal. The results showed that one bag of NPK fertilizer can produce, on average, 5 to 6 bags of food grains. Thus, the volume of food grains transported from the Terai to the hills could be reduced by more than 80 percent. This would significantly relieve the financial burden on the government every year.

An analysis of the results indicates that crop yields could be increased by 55-60 % over the present level if farmers would make use of judicious amounts of fertilizers and related inputs. In fact, the yield increases were more than 100% above those in the control plots where no fertilizers were applied and this applies to all four crops (Table 2).

In recent years, the use of mineral fertilizers has increased because of the inadequacy of farmyard manure and farmers are realizing that decreased crop productivity is due to the decline in soil fertility. The above recommendations would be appropriate for crops under irrigation in river valleys, tars and hill slopes with humid-sub-tropical-to-warm temperate climate. However, arguments are being raised about the sustainability of the increased productivity even with the use of the same fertilizer rates over the years. Before making any conclusion, long term evaluations and assessments are needed to support this statement.

5. IS INTEGRATED SOIL FERTILITY MANAGEMENT AN APPROPRIATE ALTERNATIVE?

For centuries, farmers in Nepal have been practicing different indigenous soil fertility and plant nutrition management systems through crop-livestock-forest integration. However, alone they might not be adequate to sustain the agricultural productivity needed to feed the growing population. Therefore, a combination of all possible practices including mineral fertilizer use as part of the "Integrated Soil Fertility and Plant Nutrients management Systems" could be an appropriate alternative for sustainable agricultural development.

Table 2. Yield Comparison Between Fertilized V/S Non-fertilized and Farmers' practice in Rice, Maize, Wheat and Potato.

Nutrient Rates $N-P_2O_5-K_2O$ kg/ha	Yields kg/ha	Yield Increases Over Farmers' Plot kg/ha	%	Nutrient Rates kg/ha	Yields kg/ha	Yield Increases Over Farmers' Plot kg/ha	%
Rice				Maize			
Farmer	2,937.5	0	0	Farmer	3,242.0	0	0
60-0-0	3,854.9	917.4	31.2	60-30-20	4,084.9	849.2	26.0
90-30-30	4,577.9	1,640.4	55.8	20-60-40	4,723.8	1481.8	47.7
0-0-0	2,170.4	-761.1	-26.1	0-0-0	2,433.8	-808.2	-25.0
Wheat				Potato			
Farmer	2,342.2	0	0	Farmer	11,656.8	0	0
60-30-20	2,955.1	612.9	26.4	40-20-50	14,728.8	3,072.0	26.4
80-40-100	3,650.0	1,307.8	55.8	80-40-100	19,790.2	8,133.4	69.8
0-0-0	1,352.7	-989.5	-42.3	0-0-0	7,001.8	-4,655.0	-39.9

Emphasis on integrated soil fertility management should be given to reduce the soil erosion, conserve water, regenerate and recycle biomass and especially to increase the supply and efficiency of plant nutrients through organic and inorganic inputs.

The main findings of the recent research work by Maskey and Bhattarai (1994); Sherchan et al., (1993); Joshy et al., (1992); Subedi and Gurung (1991); Gurung and Neupane (1991); Pandey (1991); LAC (1988) provide the basis for designing Integrated Soil Fertility Management and are briefly discussed below.

5.1. Organic Manure

A document has been developed to describe the methods of FYM/composting, its preparation, storage and application. Identification of rapid composting methods through the use of fungi (Trichoderma) inoculation is under study and initial results are encouraging.

Response to the application of different sources of organic manures (compost, FYM, poultry waste, city compost, oil cakes, bone meals, as well as in combination with mineral fertilizer) were evaluated. Response of 5 tons/ha poultry manure, 20 tons/ha FYM/compost and 100:40:30 kg/ha fertilizer NPK were found to be comparable.

A comprehensive survey and study were made on conventional composting materials as well as farmers' methods of FYM/ compost preparation, storage and application.

5.2. Biofertilizers

Azotobacter is recommended for use with cereal and vegetable crops in the higher hills in combination with organic manures. A 3-29 % yield increase is expected from its use but it was found to be ineffective in combination with mineral fertilizers.

Rhizobium is recommended for pasture and grain legumes. A number of effective strains have been identified, multiplied and distributed. A 10-65 % yield increase is expected due to inoculation of suitable strains.

5.3. Green Manure

A number of local plant species have been identified as suitable for green manuring purposes. Their manure value in nutrient cycling and soil organic matter enrichment also were evaluated. Some 30-60 kg of N/ha could be produced through green manuring in rice fields.

5.4. Legumes in Farming Systems

Legumes are grown in approximately 262,000 ha in Nepal and legumes rank fourth in production after rice, maize and wheat. However, the acreage under legumes is negligible in the hill regions except for some areas where soyabean, groundnut and black gram are grown as mixed/relay cropping with maize. However, pasture legumes and several leguminous trees (used as fodder, composting materials and green leaf manuring) are extensively grown in the hill farming systems, and even a slight improvement in their N fixing efficiency could bring substantial amounts of atmospheric N into the soil system. Rhizobium inoculation should receive more attention in the cropping system research and the recent initiatives by the International Crop Research Institute for the Semi Arid and Tropical Agriculture (ICRISAT), the Australian Centre for International Agricultural Research (ACIAR) and NARC are a first step.

5.5. Fertilizers

Ampie information has been generated for fertilizer use and crop response. As a result, district specific recommendations are now available.

5.6. IPNS

Various IPNS combinations were tested in different agro-ecological regions in collaboration with FAO IPNS Network Program. The results are being extended to farmers through NARC's Outreach Research Sites. A number of coordinated long term soil fertility experiments based on IPNS principles are on-going in different ecological zones of the country.

5.7. Watershed Management

A better base for sustainable agriculture could be realized if watersheds would be managed efficiently using integrated soil fertility management systems in combination with alternate land use such as agroforestry, horticulture, pasture, fodder trees and soil, water and vegetation conservation practices.

6. CONSTRAINTS TO INTEGRATED SOIL FERTILITY MANAGEMENT SYSTEMS (ISFMS)

There are a number of constraints in ISFMS and their extension at the farm level. Some of them are:

1. An already depleted natural resource base: Regeneration of the degraded biomass in the system is a pre-requisite for the effective promotion of ISFMS. The ISFMS as a concept already exists in most farming communities. What is urgently required is the build-up and management of suitable biomass in the system.

2. Lack of institutions to regulate the production, supply and distribution of green manure seeds, biofertilizer inoculum, leguminous forage/fodder seeds and seedlings, to support the extension of ISFMS. There is a high demand for these items by the farmers and some farmers have been importing green manure seeds from neighbouring states in India. Many more are interested but are reluctant to put their land under green manure seed production because of its initial economic disadvantage in relation to alternative crops.

3. Lack of extension service to promote ISFMS at the farm level. The existing research and extension services were created to replace the traditional agricultural system with modern inputs such as fertilizers, agrochemicals, high yielding seed varieties and farm machineries. Now, there is an increased fear that the high inputs-based modern technology is overexploiting the resources and creating a natural imbalance at the cost of future generations. Therefore, an overall shift towards more sustainable and environmentally friendly technology is essential.

   Although, most extension workers know the positive effects of ISFMS, they have not been able to take it to the farmers. The approach has to be changed from uni-modal to multi-modal, non-renewable purchased inputs to renewable locally generated inputs, from individual contact to group mobilization, from plot demonstration to block demonstration and so on. Therefore, the extension service needs to be reorganized and refocused.

4. Lack of adequate research information: a blanket recommendation for ISFMS cannot be made. It needs to be adjusted to local conditions and the researchers and extension specialists should be able to show the farmers how crop nutrient requirements can be balanced using local resources in combination with fertilizers. At present, research information is scarce and it is difficult to formulate the best combinations of nutrient sources given the available resource base in the hills.

5. Labour intensive and time taking technology: ISFMS is a labour intensive and slow responding technology. Farmers may not accept it when it is introduced for the first time because it may be expensive and the risk for crop failure is high. Nevertheless, if it is developed as a method of utilizing the byproducts and wastage of the farming system, farmers will, no doubt, adopt it. For example, if compost making and application is calculated as a sole farm activity no economist may consider it as an economically viable practice. Even farmers may abandon it. However, if integrated with livestock raising, it is simply a byproduct. The farmland would be the best site for waste disposal and provide a valuable nutrient input for food production. By greater recycling the system becomes sustainable.

6. Lack of long term land use policy by the Government: the ISFMS is also a biomass-based approach. In some cases it may conflict with crop production in cultivated land and many farmers like to import biomass from external sources. The forest has been an outside source of fodder and litter for livestock and in the process is producing FYM. Because of economic and demographic pressure the forest surrounding the farm land is overexploited. The frequent change of the government policy in the use of forest resources as "public goods/ common property" has also been responsible for aggravating forest/ pasture land degradation. A sound land use policy which regulates forest use is absent. It has resulted in a negative agricultural and environmental balance. This component has been seriously considered in the forthcoming 25 years' Agriculture Perspective plan, which is now under review for approval.

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