Indian Journal of Agricultural Economics
Vol.77, No.3, July -September 2022

Replenishing Indian Soils through Industrial Waste Management: Need for Interlinking Industry and Agriculture[⁑]

Vishwa Ballabh and Aman Dubey*

ABSTRACT

The green revolution technology has contributed enormously to increasing the production and productivity of agriculture, but this has also led to demineralisation of Indian soils. The declining trend of macro and micronutrients in Indian soils have been observed in almost every part of the country. Tata Steel has developed slag-based gypsum (SBG) which has the potential to remineralise Indian soils. This paper discusses the development of SBG, its benchmarking, and experimental results obtained by the reputed agricultural universities and institutions from the application of SBG. The paper further discusses the market potential and entry barriers for the product. It is argued that all the stakeholders are likely to be positively affected by the application of SBG including the environment, however, pragmatic policies are required to support it, particularly during the initial period of launch.

Keywords : Demineralisation of soils, slag-based gypsum (SBG), Soil conditioner and Fertiliser Public Policy, Interlinkage between industry and agriculture
JEL : L71, O13, O14, Q16, Q53

I

INTRODUCTION

Indian agriculture is no doubt at crossroads, from a net importer of food grain, we have not only achieved self-sufficiency in food grain production and increased production of many other agricultural products like milk, vegetables, oilseeds, pulses, and fruits but also have exported these products *albeit* occasionally. However, these achievements have not been without a cost. The biggest brunt of this achievement has fallen on the Indian soils, which have degraded at an alarming rate. Thus, natural resource systems and agriculture are under severe stress leading to distress among the farming communities, because to compensate for the loss of productivity the farmer has to keep on increasing inputs which lead to an increase in their cost of production. In addition to land degradation, 17.93 mha of land in India is acidic soil and 6.68 mha is sodic and saline soil. The acidity, salinity, and alkalinity are caused partly by geological formation and partly by man-made reasons such as excess and faulty irrigation practices, poor soil, water, and crop management. As per ICAR-CSSRI

---

* Professor, XLRI School of Management, Jamshedpur (Jharkhand) and Formerly Research Associate, XLRI – Jamshedpur, presently PGDBM scholar at TAPMI, Manipal, respectively.

[⁑] This paper is drawn from the project “Market Potential and Soil Conditioner: Generating Wealth from the Waste”. Financial support received from Tata Steel is gratefully acknowledged.

.

estimates every year, India loses 11.58 million tonnes of cereals, pulses, and cash crops from the 3.7 mha alkaline soil alone. Among the crops, wheat, sugarcane, potato, rice, and cotton suffer maximum losses (Sharma *et al.*, 2019). This is due to excessive irrigation and poor soil and water management.

The Government of India institutions and independent researchers have estimated the cost of land degradation in India. This estimate varies widely depending upon the methodology used. But there is unanimity among the scholars and researchers that land degradation has become a serious problem in both rainfed and irrigated areas. There are many reasons for land degradation including improper management of land resources and inappropriate cultivation practices, soil water, and forest management. These practices need to change, but the degradation of soil has led to a decline in the nutrient content of the soil. The cost of nutrient decline in the soils leads to loss of crop productivity, changes in land use intensity, changing cropping patterns, high input use and declining profit (See Joshi and Agnihotri, 1984, NRSA, 1990, Sehgal and Abrol, 1994, Joshi et al., 1996, Parikh and Ghosh, 1991, and Reddy, 2003 and Bhattacharyya et al., 2015). The role of fertiliser in increasing the production and productivity of Indian agriculture could hardly be over-emphasised. The increased doses of fertiliser were one of the important components of the green revolution technology. However, the imbalanced use of fertilisers by the farmers has also contributed towards land degradation (Chand and Pandey, 2008, Gulati and Sharma, 1995). It has been found that there is an imbalance in fertiliser use in the country and approximately one-third of the major cultivating states apply excess of N and the two-thirds of the states use less than the required level of N. The use of P was more than what was required in a few states like Gujarat, Karnataka, Punjab, and Tamil Nadu while it was deficient in Madhya Pradesh, Uttar Pradesh, and West Bengal (Chand and Pavithra, 2015). The uses of potassium were much below the required level.

As a consequence of the intensification of Indian agriculture, the Indian soils became deficient in terms of many macro and micronutrients. To begin with when India was producing 50 million tonnes of food grain at the time of independence and only nitrogen (N) was found to be deficient. The green manuring and FYM were the main sources of nutrient supplement. At the advent of the green revolution in the late 1960s with the introduction of short duration crops, nitrogen (N), phosphorous (P), and potassium (K) were found to be deficient in the soil and needed to be applied as inorganic fertilizers. Overtime with multiple cropping and changes in farming systems, the space for green manuring and the application of FYM drastically reduced due to the changes in production environment and product mix adopted by the farmers. As a result, the number of elements deficient in Indian soil increased from one (N) in 1950 to nine (N, P, K, S, Zn, B, Fe, and Mn) in 2005-06. The importance of micronutrients in Indian agriculture has increased due to their deficiency and consequently their impact on agriculture production and productivity (FAI, 2018). Indian soils are found to be deficient in sulphur, zinc, boron, copper, iron, and manganese. The deficiency of sulphur and zinc is found to be an all-Indian phenomenon. At the all-India level, 67.82 per cent of the sample was found to be sulphur deficient and the maximum deficiency was found in the agricultural heartland of Haryana, Punjab, Uttar Pradesh, Andhra Pradesh, Karnataka, Telangana, and Tamil Nadu. Thus, it is no surprise that sulphur is considered the fourth most important element in crop production in Indian agriculture (Shukla *et al.*, 2018).

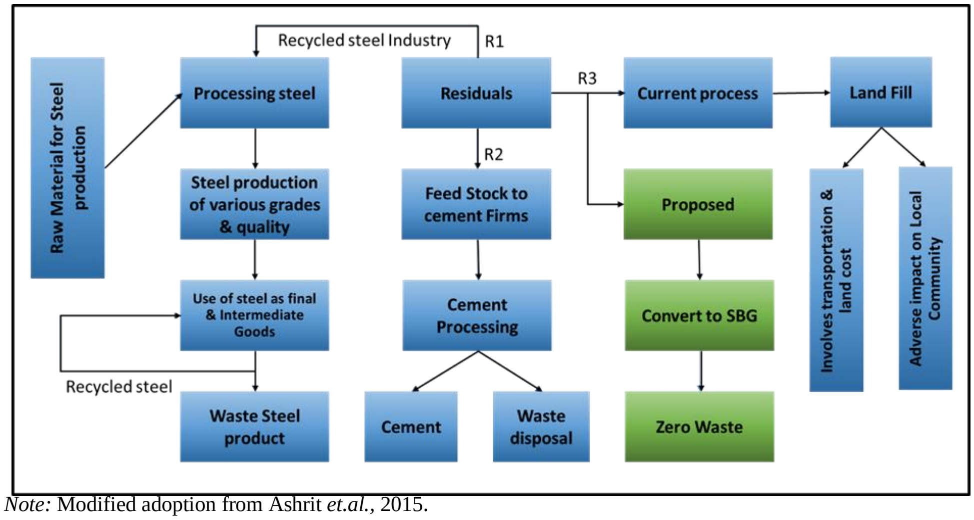
The situation of other micronutrients is not very different from that of sulphur. At all India level zinc was found to be deficient in 62.51 per cent samples (FAI, 2018). The north, east, and north-eastern regions were found to be deficient in zinc in more than 60 per cent of the samples. Zinc was also found to be deficient in coastal Andhra Pradesh, Kaveri delta, and Kerala. A similar observation was made for other micronutrients like copper, boron, iron, manganese. These data leave no room for the debate that the Indian soils are becoming impoverished and deficient in macro and micronutrients. From the available information and data, one could conclude that the Indian soils are demineralised and there is a strong need to reverse the current trend.

Several approaches could be adopted to mitigate the current situation and reverse the trend of demineralisation of Indian soils such as proper soil water conservation, watershed and participatory management of land and water, integrated nutrient management, organic and green manuring, reforestation and grassland management, diversification of agriculture, conservation and zero cost agriculture. However, there may be an alternative way of possibility to remineralisation of Indian soils by interlinking it with industry like steel which produces enormous amount of waste products containing plenty of useful minerals essential for the plant nutrients. One such product developed by the Tata Steel is slag-based Gypsum known as SBG. SBG could play a significant role as it could be used to provide supplemental macro and micronutrients such as sulphur, calcium, magnesium, zinc, copper and silica etc. Thus, the waste product could be used to generate plentiful amount of wealth. The rest of the paper to discuss the potential of SBG for agriculture is organised as follows: Section II discusses the development of the product, bench marking, and field trials conducted by the various agricultural institutions and its impact on production and productivity. Section III discusses the mapping of gains from the SBG, the potential market and threats and the final section summarises the overall findings and future strategy for the SBG application in Indian soils and reverting the declining trend of nutrients.

II

PRODUCT DEVELOPMENT, BENCHMARKING AND FIELD TRIALS

The steel industry uses non-renewable resources like iron ore, coal for manufacturing of steel. This waste generated on steel firm is divided into three parts: the first part (R1) 31 per cent metallic recoverable part is recycled and used in the steel industry itself, the second (R2) which is 49 percent of the blast furnace slag is used as a feedstock in the cement industry and finally the third part (R3) which is 20 per cent of the waste is disposed as landfills, which makes the land a permanent waste (Figure 1, Ashrit *et al*., 2015). The rejected non-magnetic portion is rich in different types of elements like calcium, silicate, zinc, sulphur, boron and termed as steel slag. Steel slag could be fruitfully utilized as a plant nutrient and as a soil amendment. But raw steel slag is not used in agriculture due to its physical properties and texture rigidities. However, steel slag could be synthesized as useful material for the application in agriculture as a soil conditioner and fertiliser. The years of experimentation at Tata Steel, led to the development of slag-based Gypsum (SBG). There were two-fold objectives of the SBG development (i) steel slag contains useful elements of plant nutrients and therefore the objective was to convert it into a usable form, as it cannot be used directly in agriculture because of its texture, and (ii) to reduce the waste disposal costs. In the steel industry the idea of SBG development was to use the non-utilised portion of steel industry waste (20 per cent) and convert it into soil conditioner and fertiliser.

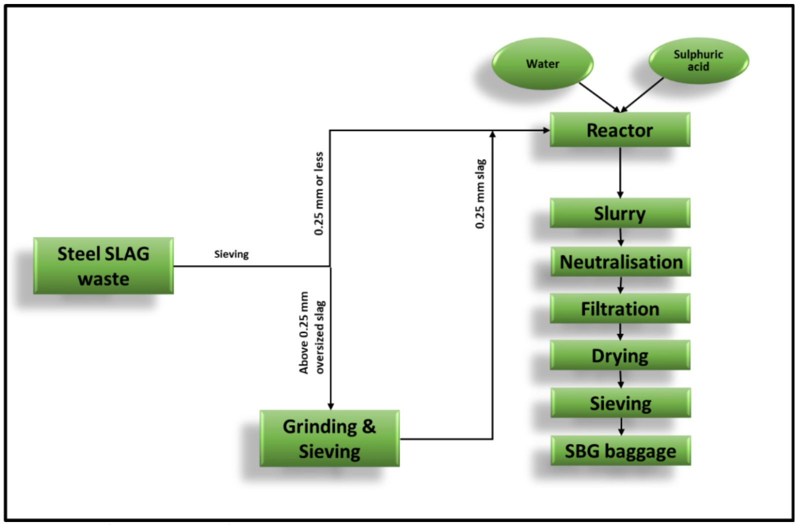


Note: Modified adoption from Ashrit *et.al.*, 2015.

Figure 1: Current and Proposed Procedures of Waste Disposal in Steel Industry

The process of making SBG is simple, firstly the steel slag from the steel plant is taken and through grinding and sieving, it is converted into a 0.25 mm fine steel slag. This material is then subjected to atmospheric leaching with concentrated sulphuric acid for a maximum of about two hours. The slurry thus made is then neutralised, filtered, and dried. Once again, the material is subjected to drying and sieving so that only fine SBG material is bagged which is suitable for applications in agriculture as a soil conditioner and/or fertiliser (Figure 2).

In developing the product, Tata Steel studied the chemical and physical properties of the steel slag. Once the product was developed, its chemical properties



Note: Modified adoption from Ashrit *et a*l.,2016

Figure 2: Systematic Representation of SBG Processing from Steel Slag

were further studied in house and also in independent laboratories such as National Test House Kolkata, National Metallurgical Lab, Jamshedpur, Bidhan Chandra Krishi Vishwavidyalaya, Kalyani, West Bengal, and Mitra SK Pvt Ltd. Kolkata. The analysis and benchmarking have been done both for desirable elements and for the hazardous impurities, the non-desirable elements. The SBG developed by Tata steel is rich in many elements essential for plants like calcium, sulphur, zinc, boron, silicate, etc. Since the neutralisation process maintain the pH of the end product between 7-8, thus it is not only suitable for both sodic and salt-affected soil but also the acidic soil primarily because of its lime content which neutralises the acidity in soils. The hazardous impurities, if any, were found to be within the limits of Bureau of Indian Standards (BIS) and European standards of soil amendments and fertiliser (for details see Ballabh and Dubey, 2020).

The chemical properties of SBG reveal that it contains various chemical elements such as calcium, sulphur, silica iron, magnesium, phosphorous, manganese, zinc and copper which are essential plant micronutrients required for plant growth. Also, these elements in soils help the plant develop resistance against diseases, improve chlorophyll formation and thus have the potential to increase crop yield. Not only this, but the product could also improve the soil structure which in turn reduces water runoff and thus reduce the soil erosion. This is because SBG has all the properties of natural gypsum. The impurities if any are within the permissible limit of BIS and European standard. Based on these findings it was concluded that the product is safe for use in agriculture and an enormous amount of wealth could be created with the use of SBG in agriculture. The SBG developed by Tata Steel has all the properties of gypsum, it can substitute mined gypsums for the use in agriculture which is presently used for the reclamation of sodic and saline soils (for details see Ballabh and Dubey 2020).

Different sources of gypsum have specific mineralogical, physical, and chemical properties. One way, therefore, is to compare SBG with mined and other gypsums like FGD gypsum, phosphogypsum, etc. This comparison demonstrated that SBG not only contains more calcium and sulphur which is an important constituent of any gypsum, but it also contains many other plant micronutrients like zinc, copper, iron, magnesium, boron, molybdenum, and silicon (in SiO_2 form). The presence of silicon in the material helps the plant to develop resistance against biotic and abiotic stresses like bacteria, fungi, viruses, insects on one hand and develop plant capacity to withstand drought and lodging on the other hand. The presence of silicon also helps the plants to survive in saline and alkaline soil and protects them from ultraviolet lights. All this is possible because it helps the plant to develop a good root system and appropriate shoot, leaves contain more chlorophyll which in turn may help proper grain formation (Patra and Acharjee, 2020, Prakash, 2019).

The results obtained from various laboratories also demonstrated that except ammonium sulphate (AS) all other synthetic fertilisers contain less sulphur than the SBG. Therefore, SBG could be a good source of sulphur. Based on the chemical analysis of the various laboratories, it may therefore be concluded that SBG does not only have all the properties of gypsum, but it is a superior product and there is a high potential for its use in agriculture both as a soil amendment to reclaim saline, sodic and acidic soils and as a fertiliser for the macro and micronutrients. The application of SBG also has the potential to improve the mineral content in Indian soils and thus restore the soil health. These results have been corroborated by the technical analysis of the product. For example, Prakash (2019) concluded that the slag-based gypsum, prepared from acid treatment contains a good amount of essential plant nutrients particularly $CaSO_4$, which could be a good source of sulphur. In addition to the calcium (2.65 per cent) and sulphur (16.91 per cent), the product contains the micronutrients like Fe (5.45 per cent), Mg (0.851 per cent), Mn (0.086 per cent) and beneficial elements like Si (3.41 per cent). This would add enormous value to agriculture, and it is concluded that the waste slag material could be converted into an asset for its use as inputs in agriculture.

Once the product's chemical and physical properties were studied, it was concluded that the product is not only unique but also superior as compared to the existing products including mined gypsum, Tata Steel approached various agricultural universities and institutions for conducting field trials and experiments. These experiments are conducted on various crops and soil types, such as neutral, acidic, sodic, and saline soils. The crops included are rice (paddy), wheat, maize, groundnut, mustard, okra, tomato, cotton, vegetables, and fruit crops (see for details Prakash (2019); Ballabh and Dubey, 2020). The experiments are conducted by the reputed agricultural universities like the University of Agricultural Sciences (UAS), Bengaluru; Bidhan Chandra Krishi Vishwavidyalaya (BCKV) Kalyani, West Bengal;

Punjab Agricultural University (PAU), Ludhiana, Punjab; Indian Agricultural Research Institute (IARI), New Delhi and private corporates like Rallies India (Ltd).

The scope of the trials and experiments range from pot culture with and without SBG, randomised block designs with different doses of SBG and trials at the farmers' field. The impact of SBG was measured and analysed: (i) soil analysis pre- and post-application; (ii) the growth of the plant and heavy metal content of the plant during the growth phase; and (iii) the heavy metal content in the main and by-products. One of the concerns of the research teams in all the institutions was the heavy metal content in the soil, grains, and by-products. Overall, all the research institutions have found no impurities and harmful metal content in soils, main and by products of the crop. Based on these findings it is concluded that SBG applications in agriculture is safe. It is also concluded that grain and by-products are safe for human and animal consumption. In contrast, other minerals like zinc, magnesium in grains have increased *albeit* marginally which is essential for the human and animal health (Ballabh and Dubey, 2020).

All in all, it could be concluded that there was a significant increase in yield of all crops in all types of soil, neutral, acidic, alkaline and saline with SBG applications along with recommended doses of fertiliser (RDF). The application of SBG is not only safe, but also has potential to bring huge dividends because of an increase in the yield of the crops as (i) it improves nutrient uptake through proper development of root and shoot systems of the crops; (ii) it improves soil fertility and enhances micronutrients like Ca, mg, S, etc. in soil, grain and by-product and; (iii) it does not leave harmful elements in soil, grains and in by- product and all impurities remain much below the BIS and European Standards. (Patra and Acharjee, 2020, Prakash, 2019).

Based on the experimental data, the incremental returns for maize (acidic soil), maize (neutral soil), and rice crop is grown in neutral, alkaline and acidic soil are presented in Table 1 and Table 2 respectively.In order to calculate the net incremental

TABLE1: SBG APPLICATION AND INCREMENTAL RETURN IN MAIZE

Treatment (1)	Maize								
	SBG Incremental cost (INR) (2)	Hassan (Acidic soil) t/ha (3)	Incremental yield over previous dose t/ha) (4)	Incremental Return (INR) (5)	Net incremental Return (INR) (6)	Mandya (Neutral soil) t/ha (7)	Incremental yield over previous dose t/ha) (8)	Incremental return (INR) (9)	Net incremental return (INR) (10)
T1:RDF		6.55				3.84			
T2:RDF + 150kg SBG/ha	1650.00	7.01	0.46	8510.00	6860.00	4.09	0.25	4625.00	2675
T3:RDF + 300kg SBG/ha	1650.00	7.41	0.40	7400.00	5750.00	5.17	1.08	19980.00	18330
T4:RDF + 450kg SBG/ha	1650.00	7.23	-0.18	-3330.00	-4980.00	6.94	1.77	32745.00	31095
T5:RDF + 600kg SBG/ha	1650.00	8.10	0.87	16095.00	14445.00	7.77	0.83	15355.00	13705
T6:RDF + 750kg SBG/ha	1650.00	8.61	0.51	9435.00	7785.00	8.69	0.92	17020.00	15370

Source: Our own estimate based on experiment results obtained from UAS, Bangalore (See Ballabh and Dubey, 2020).

Note: The price of SBG is taken @11 Rs./kg; incremental return is valued at minimum support prices of maize fixed for the year 2020-21, i.e., INR 1850 per quintal https://pib.gov.in/PressReleasePage.aspx?PRID=1628348

TABLE 2. SBG APPLICATION AND INCREMENTAL RETURN IN RICE

Treatment (1)	Rice												
	SBG Incremental cost (INR) (2)	Mandya (Neutral soil) t/ha (3)	Incremental yield over previous dose (t/ha) (4)	Incremental return (INR) (5)	Net incremental Return (INR) (6)	Chamaragan ga (Alkaline soil) t/ha (7)	Incremental yield over previous dose (t/ha) (8)	Incremental Return (INR) (9)	Net Incre mental Return (INR) (10)	Hassan (Acidic soil) t/ha (11)	Incremental yield over previous dose (t/ha) (12)	Incremental return (INR) (13)	Net increm ental return (INR) (14)
T1:RDF		6.69				7.52				4.59			
T2:RDF + 150kg SBG/ha	1650.00	6.84	0.15	2802.00	1152.00					4.74	0.15	2802.00	1152.00
T3:RDF + 300kg SBG/ha	1650.00	6.91	0.07	1307.60	-342.40	8.93	1.41	26338.8	23438.8	5.70	0.96	17932.80	16282.80
T4:RDF + 450kg SBG/ha	1650.00	7.05	0.14	2615.20	965.20	9.04	0.11	2054.80	404.80	5.78	0.08	1494.40	-155.60
T5:RDF + 600kg SBG/ha	1650.00	7.74	0.69	12889.20	11239.20	9.07	0.03	560.40	-1089.60	6.03	0.25	4670.00	13705
T6:RDF + 750kg SBG/ha	1650.00	8.05	0.31	5790.80	4140.80	9.22	0.15	2802.00	1152	6.15	0.12	2241.60	591.60
T6:RDF + 900kg SBG/ha	1650.00					8.88	-0.34	-6351.20	-8001.20				

Source: Our own estimate based on experiment results obtained from UAS, Bangalore (See Ballabh and Dubey,2020).

Note: The price of SBG is taken @11 Rs. /kg; incremental return is valued at minimum support prices of rice fixed for the year 2020-21, i.e., INR 1868 per quintal https://pib.gov.in/PressReleasePage.aspx?PRID=1628348.

returns from various doses of the SBG application, the yield data was taken from the experiment conducted by UAS, Bangalore. The control plot yield was taken for the treatment in which SBG was not applied but all other inputs were used at the recommended level (RDF). The price of SBG was taken as Rs. 11 per kg, as provided by Tata Steel Research and Development division.

The SBG treatment varied from a minimum of 150 kg per hectare to a maximum of 900 kg per hectare and the soil condition varied from acidic, alkaline, and neutral at various research stations. It may be seen from Table 1 and Table 2 that the net incremental return is positive up to 750 kg per hectare in both the crops and in almost all types of soil, with few exceptions in the treatment. However, the net incremental return in maize is highest at 600 kg per hectare SBG application in acidic soil and 450 kg per hectare in neutral soil. Similarly, for the rice crop, the highest incremental return was found to be at the rate of 600 kg per hectare application in neutral soil, 300 kg per hectare application in acidic soil, and alkaline soil. These results point out that the rate of application of SBG should be determined by detailed soil analyses. But as a thumb rule, wherever soil testing is not available, the application of 300-750 kg per hectare would lead to an additional net increment from Rs. 15,000/- to Rs.30,000/- per hectare in these crops. Based on these results one could safely conclude that the application of SBG in agriculture is not only safe but could bring a new revolution in increasing production and productivity and also redeem the health of Indian soils which is fast deteriorating in their physical and chemical properties. The large-scale application of SBG in agriculture has the potential to contribute to increasing farmers' income, thereby contributing to the government's current policy thrust of doubling the farmer's income.

III

MAPPING GAINS, MARKET POTENTIAL, AND THREATS

It is important at this stage to understand the gains and losses from the introduction of SBG in the market for the different stakeholders. There are three important stakeholders who would be directly impacted by the product's entry into the market. First and foremost, the farmers who are targeted as a customer of the SBG product, the second group of stakeholders would be the steel firms and industry and the third group is the society at large (Table 3).

TABLE 3: GAINS FROM USE OF SBA TO VARIOUS STAKEHOLDERS

Farmers (1)	Steeel industry (2)	Society (3)
Increased production and productivity	Reduced waste disposal cost	Environmental protection
Reduced cost of crop production	Additional revenue	Restoration of soil health
Increased income and investment capacity	Increased farm-firm linkage	Sustainable agricultural system
		Moving towards balanced use of fertiliser and nutrient management

Source: Ballabh and Dubey, 2020.

It is evident from Table 3 that the product would create a win-win environment for all the three major stakeholders. The farmers gain from the reduced cost of production and increased productivity and income. The steel firms are benefited from the reduced cost of waste disposal and increased additional revenue from the waste. This would also help them built linkages between the farm and steel firms. Elsewhere, it is demonstrated that the Society gains from the environmental protection, restoring of soil health and moving toward sustainable agricultural practices and balanced fertiliser use. Thus, the social impact of the product will be positive (see for details Ballabh and Dubey, 2020). Since the social value is higher than the private gains from the application of SBG in agriculture and therefore it makes sense for the government to ensure all support including subsidies. The involvement of the government should create a win-win situation both for the farmers, steel firms and the environment. The government would also achieve its own objective of doubling the farmer's income.

There are three alternative opportunities to promote SBG in the market: (i) as a soil conditioner and amendment to the soil; (ii) promote it as a fertiliser within the sulphur category; and (iii) customised sulphur multi-micro nutrients fertiliser developed to bring prosperity on the farming community and improves the soil health. The positioning of the product would determine the market size. As a substitute for natural gypsum SBG could be applied for reclamation of problematic soil and estimated market size will be in order of 11 -18 million tonnes (Table 4), however if SBG is treated as a sulphur based fertiliser, the market size will increase to 46-72 million tonnes. But the full potential of the product could be realised by promoting SBG as a unique product customized for sulphur with multi-micronutrients. The estimated market size could go up to 64-146 million tonnes. Thus, the requirement for the product will not be a limiting factor given the existing capacity of the steel industry.

TABLE 4: ESTIMATED REQUIREMENT OF SBG

Sl. No (1)	Particulars (2)	Area (mha) (3)	Level of usage (kg/ha)		Requirement (million tonnes)	
			Low (4)	High (5)	Low (6)	High (7)
(A)	Gross sown area	195	450	750	87.75	146.25
(B)	Net sown area	141	450	750	63.45	105.75
(C)	Problematic soil	24.58	450	750	11.06	18.44
(D)	High sulphur intake crops					
	Rice		450	750	19.7	32.83
	Wheat		450	750	13.34	22.24
	Pulses		450	750	7.45	12.41
	Oilseed		450	750	6.0	10.01
	Sub-total (D)	103.31	450	750	46.49	77.48
(E)	High sulphur deficient states	93	450	750	41.85	69.75

Source: Ballabh and Dubey 2020.

The potential threat for the product comes from the natural mined gypsum. The mining of gypsum creates several environmental problems including wastage of water and pollution to local environment. In spite of these adverse impacts, government provides subsidy and encourages its use in agriculture for the reclamation of saline and alkaline soils. If this continues the SBG would not be able to compete in the market. There are two ways, either government removes the subsidy from gypsum for agriculture and other uses or the same subsidy may also be provided for the SBG for its use in agriculture. Projection of the product as sulphur-based and other multi-micronutrients may also face stiff competition with existing sulphur-based fertilisers and high value foliage-based micronutrients products. However, there is no doubt that SBG is a superior product as the experimental results have shown about its potential to replenish Indian soil with micro-nutrients, it requires pragmatic policies to support the usage in the initial years.

IV

SUMMING UP

Indian agriculture has made unprecedented achievements since the advent of the green revolution in the 1960s. However, these achievements are not without cost, and much of the brunt is borne by the agricultural production system, and land, water, and soils are becoming degraded. As a result, the farmer has increased the supplemental input leading to an increase in their cost of production. Therefore, it is important that demineralisation of Indian soils is arrested. Tata Steel has developed slag-based gypsum (SBG) which could be fruitfully utilized to supplement macro and micronutrients and generate an enormous amount of wealth by increasing the production and productivity of agriculture. In this paper, the experimental results obtained from the laboratories and field trials conducted by reputed agricultural universities and institutions are reviewed and it was found that the product is of high quality and have potential to increase the farmers’ income. It is suggested that the product may be introduced as a soil conditioner or sulphur-based multi-nutrient fertiliser. It has the potential to benefit the farmers, the steel industry and will have a positive environmental impact. Thus, a win-win situation for all the major stakeholders. The policy environment, however, is not favourable for the product due to heavy subsidies provided by the government to mined gypsums which are used to reclaim sodic and saline soils. Pragmatic public policy support for the SBG product would go a long way to replenishing Indian soils with macro and micronutrients.

REFERENCES

Ashrit, S., Banerjee, P. K., Chatti, R. V., Rayasam, V., and Nair, U. G. (2015), “Synthesis and Characterization of Yellow Gypsum from LD Slag Fines Generated in a Steel Plant”, *Current Science, Vol.*109, No.4, pp.727-732.

Ashrit, S., Chatti, R. V., Udpa, K. N., Venugopal, R., and Nair, U. G. (2016), “Process Optimization of Yellow Gypsum Synthesized from LD Slag Fines- An Opportunity for Value Addition of LD Slag”, *Metallurgical Research Technology*.

Ballabh, Vishwa and Dubey, Aman (2020), *Market Potential and Social Impact of LD Slag-Based Soil Conditioner: Generating Wealth from the Waste*, Report submitted to R & D Department, Jamshedpur, Tata Steel.

Bhattacharyya, R., Ghosh, B. N., Mishra, P. K., Mandal, B., Rao, C. S., Sarkar, D., and Franzluebbers, A. J. (2015), "Soil Degradation in India: Challenges and Potential Solutions", *Sustainability*, Vol.7, No.4, pp.3528-3570

Chand, R., and Pandey, L. (2008), *Fertiliser Growth, Imbalances and Subsidies: Trends and Implications*, National Centre for Agricultural Economics and Policy Research, New Delhi.

Chand, R., and Pavithra, S. (2015), "Fertiliser Use and Imbalance in India: Analysis of States", *Economic and Political Weekly*, Vol.50, No.44.

Fertiliser Association of India (FAI) (2018), *Fertilizer Statistics* (2017–2018), New Delhi.

Gulati, A., and Sharma, A. (1995), "Subsidy Syndrome in Indian Agriculture" *Economic and Political Weekly*, A93-A102.

Joshi, P. K., S. P. Wani, V. K. Chopde, and J. Foster (1996), "Farmers' Perception of Land Degradation: A Case Study," *Economic and Political Weekly* A89-A92.

Joshi, P. K., and A. K. Agnihotri (1984), "An Assessment of the Adverse Effects of Canal Irrigation in India", *Indian Journal of Agricultural Economics*, Vol.*39*(902-2018-2320), pp.528-536.

National Remote Sensing Agency (NRSA) (1990), *IRS -Utilisation Programme: Soil Erosion Mapping;* Project Report National Remote Sensing Agency, Hyderabad, India.

Parikh, K. and U. Ghosh (1991), *Natural Resource Accounting for Soil: Towards and Empirical Estimate of Costs of Soil Degradation for India*'; Discussion Paper No. 1991, 48; Indira Gandhi Institute of Development Research, IDEAS: Mumbai.

Patra, P. K., and Acharjee, P. U. (2020), Annual Greenhouse and Field Cultivation Report on Application of Yellow Gypsum in Rice, Mustard and Okra. Bidhan Chandra Krishi Vishwavidyalaya, Agricultural Chemistry and Soil Science, Mohanpur, Nadia, West Bengal.

Prakash, N. B. (2019), *Slag Based Gypsum as a Source of Sulphur, silicon and other Micronutrients in Agriculture.* University of Agricultural Sciences, GKVK, Department of Soil Science and Agricultural Chemistry, Bengaluru.

Reddy, V. Ratna. (2003), "Land Degradation in India: Extent, Costs and Determinants." *Economic and Political Weekly*, 4700-4713.

Sehgal, J. L., and I. P. Abrol. (1994), *Soil Degradation in India: Status and Impact*, Oxford & IBH Publishing Co., New Delhi.

Sharma, P. C.; Kumar, A., Kumar, P., and Singh, A. (2019), "*ICAR-CSSRI at a glance"* Karnal: CSSRI

Shukla, A. K., Behera, S. K., Pakhre, A., and Chaudh (2018), Micronutrients in soils, plants, animals, and humans. *Indian Journal of Fertilisers, 14(3),* 30-54, FAI, New Delhi.

Shukla, A. K., Behera, S. K., Pakhre, A., and S. K. Chaudhari (2018), Micronutrients in Soils, Plants, Animals and Humans", *Indian Journal of Fertilisers*, Vol;*14*, No.3, pp.30-54.