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Litter decomposition & nutrient release patterns of a dry tropical forest ecosystem

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Abstract

Litter fall represents an essential link in organic production decomposition cycle, and this is a fundamental ecosystem process. Studies on litter production and nutrients release through litter decomposition in forest ecosystems are of great importance to understand the nutrient cycling, energy flow, primary production etc. The biomass increment of overstorey and understorey was estimated from the gbh/dbh values of respective periods following the regression equation procedure. Herbaceous biomass was calculated in different years following harvest procedure. The total net vegetation production of a given sample plot of forest type is measured by adding the respective production of OS, US and GS vegetation; fine root (peak) and leaf litter fall. The whole leaf biomass production is added to forest floor in the form of litter within annual cycle, as these forests are dry deciduous type. The total forest floor biomass varied from 1.84 Mg ha^{-1} to 3.51 Mg ha^{-1} in different forest types during all the three seasons. The total standing litter biomass of vegetation (OS+US+GS) was 36043.82 Mg in entire study area. The forest type wise standing litter biomass varied from 2885.08 Mg to 12203.18 Mg. Total N and C storage in litter (leaf+wood+twig) varied from 13.0 to 17.04 kg ha-1, and 70.67 to 205.37 kg ha-1, respectively in different forest types. The soil texture of Teak forest, Sal mixed forest and Dense mixed forest is considered as loamy soil type with the help of textural triangle (USDA) procedure. Whereas, Open mixed forest and Degraded mixed forest had sandy loam texture.

Keywords: *Litterfall, Nutrient dynamics, Biomass production, Decomposition*

Introduction

Energy flow and nutrient cycling are essential for the functioning of an ecosystem. Litterfall is a fundamental process in nutrient cycling and it is the main means of transfer of organic matter and mineral elements from vegetation to the soil surface (Vitousek & Sanford 1986; Regina et al. 1999). The analysis of litter quality and quantity and its rate of decomposition are highly important for the understanding of energy flow, primary productivity and nutrient cycling in forest ecosystems. Quantification of the nutrient flux associated with litterfall is important to the understanding of ecosystems dynamics.

The maintenance of natural systems or soil fertility in tropical forest ecosystems is achieved by high and rapid circulation of nutrients through the fall and decomposition of litter. The decomposed litter is also the basis of many food chains in tropical forests and is a principal source of energy for the saprobiota of the forest floor and soil, where the trophic chain of detritus predominates (Ola-Adams & Egunjobi 1992; Oliveira & Lacerola 1993; Regina et al. 1999).

Materials and methods

Study area

The study on “litter decomposition & nutrient released patterns of a dry tropical forest ecosystem” was carried out in part of Barnowpara Sanctuary, Raipur Forest Division, Chhattisgarh, India. The watershed comprises an area of 165.64 km^2, of which different forests cover more than 70 per cent area. It is situated between 21° 20′ to 21° 28' north latitudes and 82° 21' to 82° 26' east longitudes. The soils of study area are quite variable in their physical and chemical properties. Soils were grouped into three classes *viz*., *Inceptisols, Alfisols* and *Vertisols* and classification is done by International method.

Estimation of Forest Floor Biomass (Standing litter)

Standing litter crop was measured by randomly laying three 0.5 x 0.5 m quadrates on forest floor in each marked sample plot (20 x 20 m) of a forest type. In total, standing litter was measured in 15 sample plots (3 traps x 5 quadrates) from each forest type. Litter collected from the sample plots were separated into wood, leaf, fruit, flowers and bark components and these were oven dried at 80° C for three days till to achieve constant weight. Later, the weights of dried samples of different components were taken and summed to obtain standing litter. Later litter values were extrapolated to Mg ha^{-1} basis.

Nutrient analysis

The collected soil samples were chemically analyzed in triplicate for available N. Nitrogen was determined by Micro-Kjeldahl method by digesting 0.5 g of soil sample in 10 ml conc. H_2SO_4 and catalyst mixture of Na_2SO_4 and $CuSO_4$ (5:1 by wt.) followed by distillation and titration.

The amounts of nutrients and C in soil were determined by multiplying soil volume, bulk density and respective concentrations of C and nutrient values for given soil depth corresponding to each forest type. These values converted into kg ha^{-1}.

Statistical analysis

The data on litter crop and nutrient status of soil was analyzed in one-way analysis of variance. The significant difference between treatment means for all parameters were tested at $P < 0.05$ using least significant difference test (Gomez & Gomez, 1984). The analysis of variance was performed in MSTAT-C statistical package and correlation and regression analysis were done using curve fit program in SPSS statistical software under PC environment.

Results and discussion

Standing forest floor

The standing state of forest floor biomass of different forests is presented in Table 1. The litter in different components for various forest types was in the order: leaves> wood> twigs. The total standing litter in different season followed the order: summer > winter > rainy. Similar studied done by several workers (Singh 2002; Dhaulakhandi & Rajwar 2005).

Total forest floor biomass

Total forest floor biomass was calculated by summing the total value of all the components: leaf litter, wood litter and twig litter of three different seasons. The total forest floor biomass varied from 1.84 Mg ha^{-1} to 3.51 Mg ha^{-1} in different forest types during all the three seasons. It was highest in summer and lowest in rainy season. In summer, winter and rainy season litter crop varied between 36.41- 44.44 %, 28.62-35.33 % and 26.94-28.26 %, respectively to the total annual forest floor biomass.

The contribution of foliage, wood and twigs varied from 62.96-68.01%, 17.39-21.08 % and 9.78-14.52 %, respectively to the total forest floor biomass. Dense mixed forest had 1.10, 1.18, 1.16 and 1.91 times higher forest floor biomass than Teak forest, Sal mixed forest, Open mixed and Degraded mixed forest. The total forest floor biomass was statistically similar in Sal mixed forest and Open mixed forest (Table 1).

Forest-wise standing litter biomass

The total standing litter biomass of vegetation (trees + shrubs +herbs) was 36043.82 Mg in entire study area. The forest type wise standing litter biomass varied from 2885.08 Mg to 12203.18 Mg. It was highest in Open mixed forest followed by Dense mixed forest, Teak forest, Degraded mixed forest and it was lowest in Sal mixed forest (Table 1).

Table 1: Standing litter biomass of different forests (Mg/ha)

Forest type	Summer				Winter				Rainy			
	Leaves	Wood	Twigs	Total	Leaves	Wood	Twigs	Total	Leaves	Wood	Twigs	Total
Teak	0.93	0.27	0.19	1.37	0.59	0.21	0.12	0.92	0.61	0.18	0.08	0.88
Sal mixed	0.92	0.23	0.16	1.31	0.56	0.17	0.10	0.85	0.54	0.19	0.07	0.80
Dense mixed	0.95	0.29	0.27	1.51	0.64	0.24	0.14	1.02	0.62	0.21	0.10	0.98
Open mixed	0.92	0.20	0.20	1.32	0.54	0.21	0.12	0.87	0.56	0.17	0.09	0.82
Degraded mixed	0.45	0.12	0.09	0.67	0.41	0.10	0.08	0.65	0.35	0.10	0.01	0.46
CD at 5%	0.05	0.03	0.03	0.07	0.03	0.02	0.02	0.05	0.01	0.01	0.0089	0.02

N, P, K and C concentrations in different components of litter in different forests

Results on total C, N, P and K concentrations in different components of litter (leaves, wood and twigs) in various forest types are depicted in Figure 1. In general, the N, P, K concentration in litter followed the order: leaves>twigs>wood.

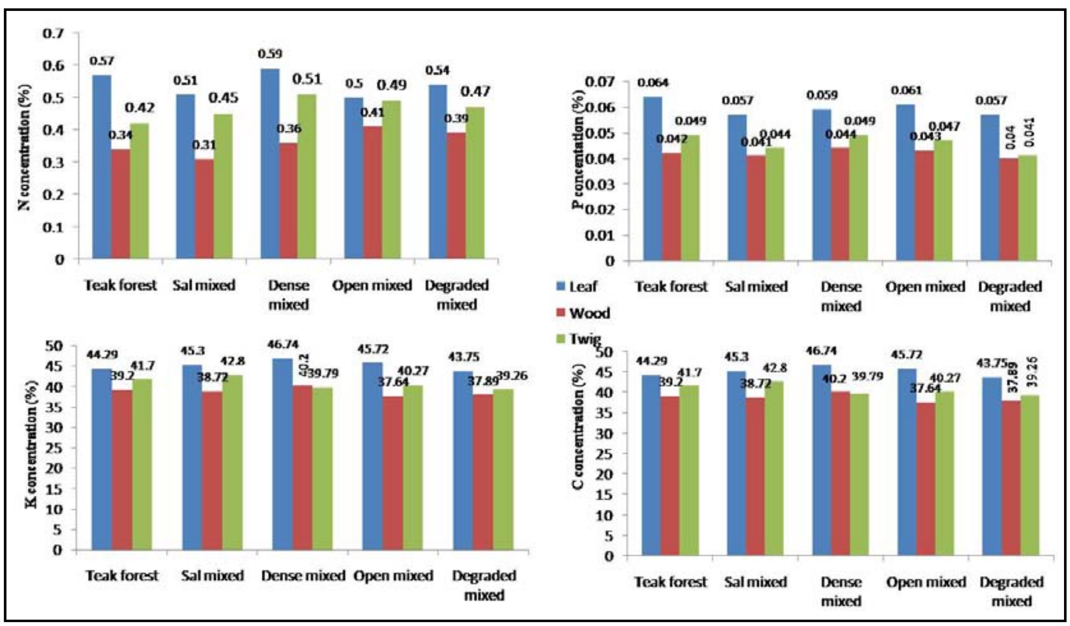

Figure 1: Concentrations of different elements in litter in different forest types

Total N, P, K and C storage in litter

Total N, P, K and C storage in litter (leaf+wood+twig) varied from 13.0 to 17.04 kg ha^{-1}, 0.89 to 1.91 kg ha^{-1}, 4.60 to 10.39 kg ha^{-1} and 70.67 to 205.37 kg ha^{-1}, respectively in different forest types (Table 2). Nutrient content varied significantly in different forest types. N, P, K and C contents were highest in Open mixed forest and lowest in Degraded mixed forest.

Table 2: Carbon and Nutrient contents in different components of litter in different forests (Kg/ha)

Forest type	N				P				K				C			
	Leaf	Wood	Twig	Total	Leaf	Wood	Twig	Total	Leaf	Wood	Twig	Total	Leaf	Wood	Twig	Total
Teak forest	12.14	2.24	1.64	16.02	1.36	0.27	0.19	1.82	6.82	1.78	1.13	9.73	94.3	258.7	162.6	516
Sal mixed	10.3	1.83	1.02	13.15	1.15	0.24	0.14	1.53	5.86	1.83	0.82	8.51	915	228.4	141.2	1285
Dense mixed	11.92	2.08	1.47	15.47	1.19	0.25	0.2	1.64	6.87	1.33	1.31	9.51	944	233.2	163.1	1340
Open mixed	11.05	3.03	2.09	16.17	1.35	0.32	0.24	1.91	7.07	1.85	1.47	10.4	1010	278.5	205.37	1494
Degraded mixed	5.32	1.25	0.7	7.27	0.69	0.13	0.07	0.894	3.51	0.64	0.45	4.6	529	121.3	70.67	721

Annual litter fall

The annual Litter fall pattern in different forest types are presented in Table 3. The maximum was estimated in Degraded mixed forest followed by Sal mixed forest, Dense mixed forest.

Table 3: Annual litter fall of different forest (Mg/ha)

Forest type	Winter				Summer				Rainy				
	Leaves	Wood	Twigs	Total	Leaves	Wood	Twigs	Total	Leaves	Wood	Twigs	Total	GT
Teak	1.155	0.427	0.170	1.752	0.918	0.195	0.090	1.203	0.983	0.127	0.082	1.192	4.147
Sal mixed	1.032	0.352	0.155	1.539	0.778	0.158	0.085	1.021	0.882	0.100	0.070	1.052	3.612
Dense mixed	0.910	0.292	0.163	1.365	0.690	0.168	0.070	0.928	0.785	0.085	0.072	0.942	3.235
Open mixed	0.982	0.407	0.227	1.616	0.867	0.190	0.072	1.129	0.933	0.098	0.080	1.111	3.856
Degraded mixed	0.540	0.143	0.090	0.773	0.537	0.105	0.010	0.652	0.442	0.067	0.055	0.564	1.989
CD at 5%	0.057	0.030	0.030	0.067	0.063	0.044	0.007	0.069	0.057	0.021	0.007	0.061	0.131

Conclusion

The total standing litter biomass of vegetation (OS+US+GS) was 36043.82 Mg in entire study area. The forest type wise standing litter biomass varied from 2885.08 Mg to 12203.18 Mg. Total N and C storage in litter (leaf+wood+twig) varied from 13.0 to 17.04 kg ha-1 and 70.67 to 205.37 kg ha-1, respectively in different forest types.

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National Science and Indigenous Cultivation in Colonial India: An Interrogation on the Contribution of Mahendra Lal Sircar, Jagadish Chandra Bose and Prafulla Chandra Ray

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Abstract
The 19th century Bengal was a fertile land that produced many geniuses. The outstanding personalities who were born in Bengal in the 19th century and who, by their thoughts and achievements moulded the intellectual, cultural atmosphere not only of Bengal but of India as a whole. Present paper gives a flavor of the Indian response to modern science by throwing some light about indigenous initiative like Indian Association for the Cultivation of Science, Bose Institute and Bengal Chemical and Pharmaceutical Works founded by the three great personalities - Mahendra Lal Sircar, Jagadish Chandra Bose, Prafulla Chandra Ray and highlighted the issues related to science at a time of colonialism and nationalism. They had rightly understood the lack of a scientific culture in our country. They desired that Indians should cultivate science for their regeneration. They also supported the nationalist cause for greater autonomy. The present paper attempts to study how these personalities' responded to modern science in colonial context and worked for the development of national science.

***Keywords**: National Science, Colonial rule, Cultivation*

Introduction
Indian nationalist science, had its engagement and contestation with European post-Renaissance knowledge, within positivism and rationality formed the vital elements. Colonization was an extremely important historical process with wide-ranging results Colonial science can be defined as 'dependent science wherein the result-oriented in applied science heavily supersedes the curiosity oriented research in pure science (Kumar 2006). George Basalla in 1967 presented a three linear evolutionary framework to explain the spread of western science in non-European areas. During Phase I, the non-scientific society provides a source for European Science, Phase II is termed colonial science; Phase III completes the process of transplantation with a struggle to achieve an independent scientific tradition or culture (Bassalla 1967). The Indian experience in Basalla's Phase II and Phase III later has been illuminated by V.V. Krishna. Krishna enquires as to who a colonial scientist actually is and places them into three categories: I. The 'gate-keepers' who helped to keep science dependent. II. The 'Scientific – soldiers' who merely executed their occupational roles and III. 'National' scientist who struggled to cultivate modern science in the framework of emerging nationalism. Krishna points out

that the third category was responsible for the emergence of national science (Kumar 2006). Nationalist thought witnessed both the effects of hegemonization by western science as well as the process of contestation between different frameworks. This process in British India, is all the more interesting for its association with nationalism, for nationalist thought itself was a contested domain. Partha Chatterjee argues that the problem of nationalist thought was a ‘peculiar manifestation of the bourgeois-rationalist conception of knowledge, established in the post-Enlightenment period of European intellectual history, as the moral and epistemic foundation of a supposedly universal framework of thought which perpetuates a colonial domination’ (Chatterjee 1986). The Scientists sought to address a wider political platform within which their science would have broader articulation and meaning. This connection between the popular nationalist discourse and the practice of science holds the key to understanding the nature of this specific transmission of science. This issue can be looked at through the frame work of the popular and the elite, defined differently (Chakrabarti 2004).The 19th century Bengal was a fertile land that produced many geniuses . It may be recalled that Raja Rammohan Roy, was the doyen of cultivation of scientific education in India. The pursuit of science and technology during his time was completely in colonial interest. The Asiatic society (1784),the Botanical Gardens (1787), the Agri-Horticultural Society (1826) and the Medical College (1834) were all institute of science but their main intention were to acquire knowledge about Indian land and people, flora and fauna, health and hygiene. Michel Foucault in his Archaeology of Knowledge and order of things has marked out the evolution of various disciplines because of social and state requirements (Kumar 1991).This paper gives an aroma of the Indian response to modern science by throwing some light about indigenous endeavour of the three great personalities - Mahendra Lal Sircar, Jagadish Chandra Bose, Prafulla Chandra Ray and highlighted the issues related to science at a time of colonialism and nationalism. They dedicated their entire life for the development of national science.

Mahendra Lal Sircar

Mahendra Lal Sircar (1833-1904) was a brilliant product of the Calcutta Medical College. He spent the greater part of his professional life campaigning for the establishment of the Indian Association for the Cultivation of Science. The association, founded in 1876 was the first to propagate modern science through lectures and demonstrations. Mahendra Lal Sircar wrote an article entitled ‘On the desirability of a national institution for the cultivation of science by natives of India’ ‘We want an institution; he wrote ‘which will combine the character, the scope and objects of the Royal Institute of London and of the British Association for the Advancement of Science. Sircar felt that the underdevelopment of India was due to its backwardness in science. Indians had the potential to master modern science and this could be achieved through self-help. He desired that Indians should cultivate science not only for ‘‘economic betterment but also for their regeneration’’ (Basu 1991). Mahandra Lal in his appeal was advocating science and the spirit to fight superstition and dogmatism and work toward national regeneration. In 1875, at the first meeting of subscribers at the senate Hall, on 4 April, Mahendra Lal said: *‘‘one of the great obstacles to the introduction of science into our schools and colleges is the paucity of indigenous teachers…the sole function of the Association will be pure science learning and science teaching apart from all bread and butter…There is at present a sad deficiency of scientific culture among our countrymen’’* (Kumar 1991). He had rightly understood the lack of a scientific culture in our country for which he wanted to create a pool of Indian scientists for the cultivation of science and its applied form. Sircar’s initiative was also praised by Sir Richard Temple. Sircar’s quest for the promotion of modern science found its first major appearance in the form of a landmark essay, published in the Calcutta Journal of Medicine in August 1869. He collaborated with Surya Kumar Goodeve Chakrabarty in setting up a Bengal branch of the British Medical Association and even became its vice-president. He was an ardent votary of Homeopathy. He will be regarded as the doyen of the scientific spirit in our country.

Jagadish Chandra Bose

If the life of Mahendra Lal Sircar highlighted the challenges faced by a pioneer in promoting the cultivation of science, the life and vocation of Jagadish Chandra Bose (1858-1937) point to the challenges faced by a practicing Indian scientist. He was a brilliant product of St Xavier’s College, University of Cambridge and London. Bose, who first came to international fame through his pioneering researches into electrical waves. Bose’s research into the similarity between the responses of metallic coherers and muscle tissues, and later, on the interconnections between the plant and animal worlds, generated considerable unease in the scientific world. However, by enlisting the support of influential scientist such as Lord Rayleigh, Lord Kelvin and Francis Darwin, he nurtured a critical but supportive audience for his scientific invention. It was of particular significance that Bose drew inspiration for his new forays from the Vedanta philosophy of his inherited cultural tradition. Bose's appeal went beyond the scientific community, to win the admiration of eminent men in different stages of life, such as Bernard Shaw, Gilbert Murray. Henry Bergson and Romain Rolland. With connection to the colonial government, Bose had a more chequered relationship. He proved to be quite skillfull in breaking into the colonial hierarchy, and taking his case directly to the Indian office in London and, at times, even to the level of the British prime minister. The most important aspect of Bose's approach towards the colonial state was to stand up resolutely to matters of principle. Bose noted a rigid caste system existing among the fields of science. Bose got the job but he was appointed only on a temporary basis, therefore, he received only half of the pay he was entitled to as an Indian, which itself was only two-thirds of a European's salary in spite of his high qualifications .Bose's version of moral resistance was to refuse to take this curtailed salary, while yet discharging his regular duties. Honoured with a knighthood and Fellowship of the Royal society, Bose's precious gift to his country was the Bose Institute, which he founded in 1917 (Lourdusamy 2004). He loved his country very much. In a letter to the nationalist leader Chittaranjan Das, Bose said that as a committed supporter of the revival of India's ancient heritage (Lourdusamy 2004). The Bose Institute was born from this resolve as a centre where the genius of India should find its true blossoming. Bose saw the institute as an embodiment of his commitment to serve India through science. Alongside research work by young scientists, the institute like the Indian Association for the Cultivation of Science, aimed to work for the advancement of knowledge with the widest possible civic and public diffusion of it and to all races and languages, to both men and women alike, and for all time coming (Bose 1916). Bose sought to give an institutional embodiment to his nationalism by founding the Bose Institute .The Institute stood as a functioning emblem of his ideas on nationalism and universalism. Bose's position among his countrymen and their appreciation of the merits of his version of nationalism was manifest in the admiration and support he drew from participants in the nationalist movement. It is interesting to note that Bose's achievements and his institute were extolled as high symbols of patriotism by a British prime minister who , quite ironically, called for action similar to that of Bose to be imitated in '' *Great Britain which is greatly in need of such manifestation of genuine patriotism''* (Nature 1924).

Prafulla Chandra Ray

If the metaphysics of Bose's science brought a distinct Indian flavor to modern science, the vocation of his contemporary, Prafulla Chandra Ray (1861-1944) stood out as a more practical fusion of the best of the east and west (Lourdusamy 2004). Acharya Prafulla Chandra Ray was a brilliant product of the University of Edinburg, and an accomplished Chemist. The first notable work of P.C. Ray which earned the international fame for him was the discovery of Mercurous Nitrite in 1895. He was an inspiring teacher. Ray embarked on a grand project to discover the scientific traditions of ancient India in his own field. Ray had a deep historical sense of mind which forced him to find out the existence of chemical science in ancient India. He took initiative to invigorate the modern chemistry in the light of ancient India's developments in chemistry. So he wrote **'**A History of Hindu Chemistry'. The first edition of this book was published in 1902 and the second edition in 1909. This work served as an inspiration for the contemporary cultivation of science by providing concrete evidence of ancient achievements which could rouse pride. He was inspired by the French chemist and historian of science Marcellin Berthelot. Apart from being a historian of science, Ray provided a staunch critique of the social causes of the Indian scientific tradition's decline. It is particularly important that in spite of being an ardent supporter of modern science he propagated Gandhi's philosophy of *charka* (spinning wheel), which advocated home spinning and which was also a very visible and potent symbol of nationalism at that time (Lourdusamy 2004). He remarked that *'India is just now on the threshold of a political renaissance and no political renaissance is possible without the full development of the intellectual and industrial resources of the country.'*(Ray 1962). So Ray started his "Bengal Chemical and Pharmaceutical Works (henceforth, BCPW) in 1901. He remarked that When I founded the BCPW I had not only the idea of wiping out the reproach that the Bengalese were good for nothing in business affairs, but also of making it a model institution. (Ray 1962). In connection to Ray's quality, Nature commented that 'Those who know him are fully aware, there could be no better preacher for throughout his long life he has practiced every precept he preaches with a vigour which is beyond admiration' (Nature 1937). Addresses presented to P. C. Ray on the occasion of his 71st Birthday on behalf of the councils of post- graduate teaching, Calcutta University that *'With characteristic single-mindedness you have remained wedded to the cause of science, students and the Nation. You have realized in this material age the tradition of the ancient Aryan Rishis.'* He was a great patriot. He remarked that *'Science can afford to wait but Swaraj cannot'* (Ray 1932).

Conclusion

This paper does throw some light on cultivation of national science in colonial context. These outstanding personalities by their thoughts and achievements moulded the intellectual, cultural atmosphere not only of Bengal but of India as a whole. It is a difficult tasks to portrait the scientific achievements of these personalities in this small discussion. This study is only a humble attempt in that direction. But this paper tried to analyze in this small attempt that how these towering personalities worked for the development of national science at the time of colonialism and nationalism.

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Biomass production in tropical forests: A review

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Abstract
Tropical forests are assuming great importance in the context of carbon cycle and its impact on climate change processes. Estimation of forest biomass is a key for understanding the exchange of energy flow, primary production and fluxes of nutrients in a forest ecosystem. The estimation of forest biomass at higher spatial scales becomes cumbersome and costly, therefore remote sensing techniques are increasingly used for biomass estimation at land scape, regional and biome levels. In the present study, the biomass was estimated through conjunctive use of ground and satellite data. Similar types of studies on forest biomass estimation using satellite remote sensing techniques were also demonstrated by several earlier workers. Tropical dry forests represent the major biome in India covering 46% of the total forest cover. Generally, tropical dry forests are smaller in structure and floristically less complex than wet forests. Mature dry forest converts into altered dry forest following grazing, fuel wood harvesting, selective logging and other anthropogenic activities.

Keywords: *Forest Ecosystem, biomass production, Fine roots dynamics*

Introduction
Tropical forests are one among the rich and complex terrestrial ecosystems store approximately 50% of the worlds living terrestrial carbon and also harbor variety of life forms. They are important both ecologically and economically, and have direct bearing on regulating the biosphere climate and also meeting the diverse needs of biomass. However, during last few decades increased anthropogenic perturbations, over grazing and alarming rates of land transformation caused severe environmental degradation and affected the biogeochemical cycle, biological diversity, productivity and consequently altered the global ecology (King et al. 1997). Tropical dry forest is the most widely distributed land-cover type in the tropics. As the rate of land-use/land cover change from forest to pasture or agriculture is high in tropics, therefore it is becoming increasingly important to quantify the ecosystem biomass and its annual production. Estimation of forest biomass is key for understanding the exchange of energy flow, primary production and fluxes of nutrients in a forest ecosystem.

The harvest and non-harvest techniques are usually employed for biomass estimation (Murphy & Lugo 1986). Harvest methods are commonly employed for biomass estimation of grasses and herbaceous cover in which the live and dead plant material is collected from sampling units and then oven dried at 80° C for 72 hours and weighed to determine biomass levels (Coombs et al. 1987). Biomass estimations in the natural forest systems using harvest procedures are highly cumbersome and restrict application for larger areas. However, the estimation of forest biomass is generally practiced through the use of non harvest procedures especially by adopting species specific allometric regression equations, which are mostly derived by ground enumerations of the particular species in terms of their DBH and height (variably total height or merchantable height). The linear and non-linear forms of allometric regression equations are generally employed for forest biomass estimation. The linear equations are commonly applied in plantations where growth rates are generally uniform. On the other hand, non-linear forms like log transformed and exponential models are employed in natural forests (Murphy & Lugo 1986; Brown et al. 1989).

Biomass production

Several workers estimated biomass and productivity in various forest ecosystems by using allometric methods (Murphy & Lugo 1986; Rai 1984; Brown et al. 1991). However, all these biomass estimates made by conventional techniques are only point measurements of a particular stand and have limitations in large-scale applications because they do not account intrastand/community variability in precisely estimating the biomass and become unreliable for regional and landscape level extrapolation.

Until recently biomass estimations were made by conventional methods as discussed above. However, all the methods suffer from not providing spatial pattern of biomass distribution and also temporal status. In view of this, of-late, several attempts were made to use remote sensing techniques (both aerial and satellite) for biomass estimation. The remote sensing data facilitate in reliably generating spatial distribution of vegetation as a base data for vegetation mapping. These maps when integrated with site-specific biomass levels enhances the scope for extrapolations and finally to compute reliable biomass estimations. In addition remote sensing methods also assume greater importance due to its amenability for integration with other relevant collateral data *viz*., topography, soils, climate etc. The estimation of forest biomass using satellite remote sensing was well demonstrated by several workers in the past (Benson & Degloria 1985; Franklin 1986; Cook et al. 1989; and Ravan 1994).

Tiwari & Singh (1984) mapped the forest biomass in Kumaun Himalaya, India using aerial photographs. Five forest types were identified and each type was divided into five crown cover classes. Mean crown cover for each class was determined in the field. Density and basal cover were measured on reference sites. Stand biomass was estimated by using biomass equations, mean girth and mean density on reference sites. Regression equations were developed between crown cover and basal cover, and between crown cover and stand biomass. Mean basal cover and mean stand biomass for each photo interpreted crown cover class were estimated through these equations. Forest biomass values were substituted for crown cover classes on the interpreted map.

Tiwari (1994) attempted to map the forest biomass through digital processing of IRS-IA data in Rajaji national park, Central Himalaya, India. IRS - LISS I data was classified into forest types and crown cover map was prepared. Allometric relations were developed between crown cover and basal cover and between crown cover and biomass. Using these relation’s basal cover and biomass were computed for each crown cover class of a forest type. Total biomass for each forest type was computed using mean values and the aerial extent. The average total above ground biomass density in different forest types ranged between 52.36 t ha^{-1} (plantations) and 371.08 t ha^{-1} (Sal forest).

Roy & Ravan (1996) estimated the biomass in tropical dry deciduous forest of Madhav National Park of Madhya Pradesh using two approaches viz., Homogenous vegetation stratification (HVS) and spectral response model. The classified map, NDVI map (derived from Landsat TM data in digital), and slope map were integrated to derive Homogenous vegetation strata. In second approach, empirical models were developed between spectral response and biomass. The relationships revealed that visible and middle infrared bands showed strong correlation than near infrared bands. It was also found that brightness and wetness indices are also strongly related to biomass. The biomass estimated for the entire national park through stratified and spectral response modeling approaches were compared and it showed only a small difference of 4.69 per cent between two approaches. Total biomass of the different community types of dry tropical forests ranged from 7.42 to 52.41 t ha^{-1}. Haripriya (2000) estimated the forest biomass from volume inventories of forests. The aboveground biomass densities for tropical forests ranged from 14 to 210 Mg ha^{-1}, with a mean of 67.4 Mg ha^{-1}.

Zheng et al. (2004) estimated the aboveground biomass (AGB) of Chequamegon national forest (CNF) Wisconsin USA using Landsat 7 ETM data.

Regression relationship was developed between aboveground biomass and different vegetation indices derived from satellite data. It was observed that AGB was strongly related to stand age and near infra red for hard wood forests, while the AGB for pine forests was strongly related to the corrected normalized difference vegetation index (NDVIc). Separating hardwoods from pine forests improved the AGB estimates and the estimated values from satellite data are close to the filed measured AGB. The total amount of aboveground biomass of the study area was estimated as 3.3 M tons, 76.5% that was hard wood and mixed hardwood/pine forest. AGB ranged from 1 to 358 Mg/ha in this forest.

Fine roots often constitute as little as 1% of the total biomass, the annual fine root production may constitute more than 50% of the net primary production of forests (Fogel 1988; Vogt et al. 1996). In some systems more nitrogen is returned to the soil via decomposition of fine roots than by decomposition of litter fall (Vogt et al. 1996).

Soil cores have been accepted as a suitable means of sampling, but a standard method to quantity fine roots in soil cores remains undefined. Fogel (1983; 1988) had discussed many technical difficulties. Methods vary widely and a few data is comparable directly. The difficulty of estimating fine root production and turnover is not limited to technical problems. There have been considerable conceptual problems concerning what constitutes a fine root, what assumptions are appropriate regarding the growth and death of fine roots, and how fine root production and turnover should be estimated (Singh et al. 1984).

Vogt et al. (1996) estimated the contribution of fine roots to the total dry matter input into forest floor in the range of 20-77 per cent for a variety of forests. Sundarapandian & Swamy (1998) reported the changes in fine-root biomass and net primary productivity (NPP) following conversion of tropical forests plantation at Kodayar in Western Ghats, South India. Very fine (<1 mm) and fine (>1-3 mm) root biomass and NPP were significantly altered in man-made ecosystems such as forest plantations and agro-ecosystems. Very fine-root biomass and NPP were significantly greater in natural ecosystems (biomass 2.45 and 2.63 t ha^{-1} yr^{-1}) when compared with monoculture plantations.

Majdi & Andersson (2005) studied the fine root dynamics, biomass production, and turnover in forest floor and mineral soil (0–30 cm) layers in relation to irrigated (I) and irrigated-fertilized (IL) treatments in a Norway spruce stand in northern Sweden over a 2-year period. Fine roots (<1 mm) of both spruce and under storey vegetation were studied. Fine root biomass and turnover were higher in irrigated-fertilized (IL) treatment.

Conclusion

The biomass of dry tropical forests was comparatively lower, which could be attributed to both abiotic and biotic stresses. Relatively low rain fall, lesser number of rainy days, extreme hot weather conditions in summer (April-May) and poor soil fertility lead to lower biomass in comparison to other dry tropical forests. Besides, the anthropogenic disturbances are moderate to severe in these forests. Forest fires, illicit felling and grazing problems are further degrading these forests. As most of the villagers in vicinity are greatly depend on these forests for their subsistence and livelihood. A variety of timber and non-timber forest products are regularly harvested in most unscientific manner, which affecting regeneration and recruitment of regeneration in different forests. In contrary to the present study, the higher biomass was reported in other dry tropical forests, which are ecologically rich and diverse due to high rainfall, better edaphic and topographic conditions, and lack of anthropogenic interferences resulted in higher biomass.

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Biomethanization of Municipal Solid Waste by Fungi culture with methanogens

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Abstract
Municipal Solid Waste (MSW), mainly Kitchen Waste (K) with Cow Dung (C) and Fungi Culture (F) can be used to generate energy which could save on the fossil fuels conventionally used as source of energy. In this study, the possibility was explored to mix Cow Dung with Fungi Culture for anaerobic digestion, so that energy can be generated as biogas and at the same time digested sludge can be used as fertilizer for agricultural applications. Pre-treatment of Kitchen Waste was done by alkali method. Anaerobic digestion was carried out in mesophilic temperature range of 30°C to 37°C with different fermentation slurries of 8 % total solids. Digestion was carried for a retention period of 60 days. The gas produced was collected by the downward displacement of water and was subsequently measured and analyzed. The overall results showed that blending of Kitchen waste with cow dung and fungi culture (*Aspergillus Flavus*) had significant improvement on the biogas yield.

Keywords: *Anaerobic Digestion; Cumulative Biogas Production; Kitchen waste; Fungi Culture; Cow dung; Inoculums; Aspergillus Flavus*

Introduction
The country's economy mainly depends on the energy resources available and utilized. Energy has been exploited since the prehistoric times. With the advent of industrial revolution use of fossil fuels began growing and increasing till date. The dependence on fossil fuel as primary energy source has led to global climate change, environment degradation and human health problems (Budiyano et al., 2010). With increasing prices of oil and gas the world looks towards alternative and green energy resources. Anaerobic digestion (AD) offers a very attractive route to utilize certain categories of biomass for meeting partial energy needs. AD is a microbial decomposition of organic matter into methane, carbon dioxide, inorganic nutrients and compost in oxygen depleted environment and presence of the hydrogen gas. This process is also known as bio-methanogenesis. Anaerobic digestion has the advantage of biogas production and can lead to efficient resource recovery and contribution to the conservation of non-renewable energy sources. AD can successfully treat the organic fraction of biomass (Hill 1983). AD is the controlled degradation of biodegradable waste in absence of oxygen and presence of different consortia of bacteria that catalyze series of complex microbial reactions

(McInerney et al. 1980). The process is one of the most promising for biomass wastes as it provides a source of energy while simultaneously resolving ecological and agrochemical issues (Budiyano et al. 2010).

Fungi culture (*Aspergillus Flavus*): *A. Flavus* as well as some other fungi, proved to have capacity of maturing in 3 days in an anaerobic jar (Clevstrom et al. 1983). Fungi are found to be the major decomposers of cellulose and lignin (Bennett et al. 1996). The production of cellulose enzyme is a major factor in the hydrolysis of cellulosic materials (Ghose, et al. 1987). *A. Flavus* is capable of producing endoglucanase even from sawdust and corncob. The *A. Flavus* also possess the capacity to degrade the non- starch polysaccharide in the substrate to soluble sugar (Hamyln et al. 1998). Most of the cellulolytic microorganisms belong to eubacteria and fungi can degrade cellulose. Cellulolytic microorganisms can establish synergistic relationships with non cellulolytic species in cellulosic wastes. The interactions between both populations lead to complete degradation of cellulose, releasing carbon dioxide and water under aerobic conditions and carbon dioxide, methane and water under anaerobic condition (Leschine et al. 1995). The Strain *A. Flavus* can be recommended for bioremediation programmes to clear cellulosic wastes (Betty et al. 2013).

Materials and methods

Sample Collection

Kitchen waste (K) was obtained from the canteen of Dayananda Sagar College of Engineering, Bangalore. Fresh cow dung was collected from a local cow yard in Yarab Nagar, Bangalore.

Materials/Instruments

The materials/instruments used for the purpose of this research are as follows: Weighing balance (Systronics), Gas Chromatography (CHEMITO), pH meter (Systronics), thermometer (range 0^0C to 100^0C), Borosilicate desiccators, silica glass crucibles, oven, grinding mill, temperature controlled water bath, water troughs, graduated transparent glass gas collectors and biogas burner fabricated locally for checking gas flammability. AR grade sodium hydroxide and acetic acid manufactured by Ranbaxy laboratories were used as procured without further purification.

Analytical Methods

The following parameters of Kitchen Waste and cow dung were analyzed: pH analysis: A glass electrode pH meter (Systronics) was used to monitor the pH of the sample. Total Solids (TS) and total volatile solids (VS) analysis: TS were determined at 103^0C to constant weight and VS were measured by the loss on ignition of the dried sample at 550^0C. Biogas analysis: Gas Chromatograph (Chemito 1000) equipped with a thermal conductivity detector was used to analyze the biogas sample. Hydrogen was used as a carrier gas (25 ml/min) with porapak Q column. Standard calibration gas mixture was used for calibration. The oven temperature of 40^0C, detection temperature of 80^0C and the detector current of 180 mA were used.

Biomethanation Unit

The figure (Figure 1) below shows the units of biomethanation and water bath. It consists of a temperature controlled thermo bath which is maintained at 35^0C (Chae et al. 2008) and has a bio digester. Each bio digester is connected to a means of connecting tube. A stand holds all the gas collectors. Biogas evolved is collected by downward water displacement.

Figure 1. Biomethanation unit (1) and Water bath (2)

Solids Analysis

Total solid (TS) and Volatile solid (VS) were analyzed for Kitchen Waste and Cow Dung according to standard methods (APHA, et al., 1995). Table.1 gives the solid analysis and pH data of Kitchen Waste and Fungi Culture.

Table 1. Solid Analysis and pH Data

Digester	pH	% TS	% VS
Kitchen Waste (K)	6.7	75.55	93.36
Cow Dung (C)	6.4	64.7	93.83

Inoculums

Pre-digested material from earlier experiments containing all the essential microbes (hydrolyzing, fermentative, acetogenic, methanogenic bacterial consortium and fungi culture) was used as inoculums for early start up of biomethanation process (Jagadish. H. Patil et al., 2011)

Fermentation Slurry and Inoculums preparation

Fresh Kitchen Waste was initially collected and it was grounded to paste in the mixer. Material balance was made and different slurries with 8 % total solids were prepared by varying the amount of paste (grounded kitchen waste) and Water (W) (Jagadish H Patil et al., 2013). The contents of each digester are shown in Table 2. Each digester was checked for neutral pH (i.e., 7.0), since the optimal pH for methanogenesis was found to be around 7.0 (Huber et al., 1982; Yang, S.T et al., 1987) When measured, each digester was found to have acidic pH (i.e., < 7.0), hence the contents were treated with 1 % NaOH (by volume) solution to bring them to neutral pH.

Table 2. Contents of digesters (To prepare Slurry 8% Total Solids)

Digester	K(g)	C(g)	F(g)	W(g)
D1, DK	19.2	--	--	160.8
D2, DKF	19.2	--	5	160.8
D3, DKC	17.48	2	--	160.52
D4, DKCF	17.48	2	5	160.52

Results and discussion

Anaerobic digestion of Kitchen Waste / Canteen Waste

The quantity of cumulative biogas production with time for all the digesters is given in Table 3. As shown in Figure 3, Digesters DK, DKF, DKC and DKCF commenced biogas production from 5th day and evolved flammable biogas from 9th day. Digester Kitchen Waste Blank which serves as blank for Kitchen waste commenced biogas production after 10 days and evolved flammable biogas on 20th day. The highest biogas yield was for digester DKCF (0.28 *l/gVS*). This performance could be because of optimum balance between the anaerobic bacteria consortium and amount of VS (23.76 g). This indicates digestion of Kitchen Waste and cow dung with fungi culture improves biogas yield significantly.

Table 3. Cumulative biogas for co-digestion K, C and F

Days	DK (l/g VS)	DKF (l/g VS)	DKC (l/g VS)	DKCF (l/g VS)
0	0	0	0	0
5	0	0.006	0.005	0.01
10	0.001	0.011	0.01	0.02
15	0.005	0.045	0.04	0.06
20	0.008	0.075	0.07	0.08
25	0.012	0.115	0.1	0.12
30	0.021	0.15	0.14	0.17
35	0.045	0.18	0.17	0.21
40	0.075	0.2	0.19	0.24
45	0.115	0.22	0.21	0.26
50	0.15	0.23	0.22	0.28
55	0.16	0.235	0.23	0.28
60	0.17	0.24	0.23	0.28

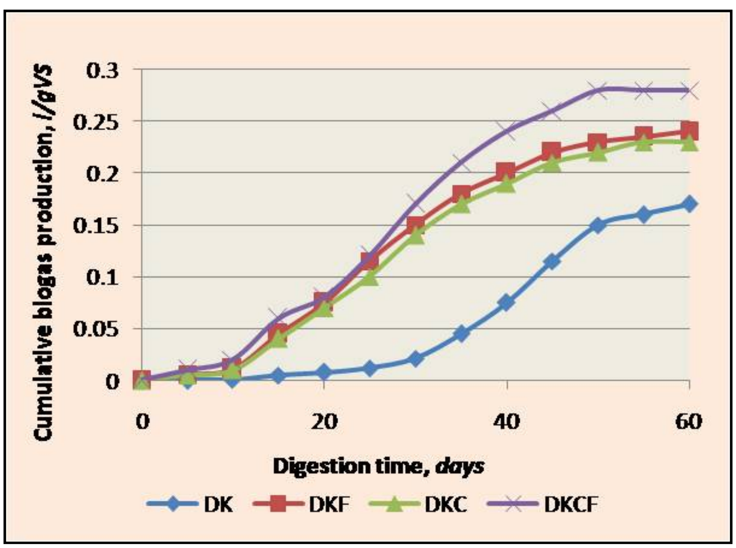


Figure 3. Daily biogas productions for digestion K, C and F

Analysis of Biogas

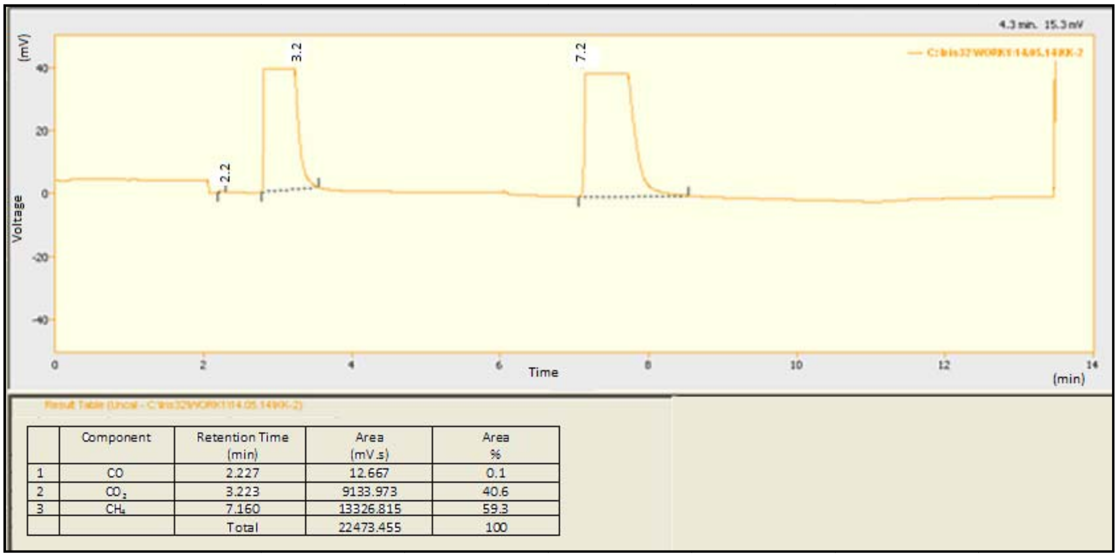
Biogas analysis was done for chief components CH4 and CO2 for biogas evolved from the digester DKCF. Biogas was sampled in a rubber bladder carefully. Gas chromatograph (Chemito 1000) equipped with a thermal conductivity detector was used to analyze the biogas sample. Hydrogen was used as carrier gas (25 ml/min) with Porapak Q column. Standard gas mixture was used for calibration. A fixed 500 µl volume was taken each time using a gastight syringe. The sample was then injected to gas chromatograph to analyze for methane and carbon dioxide. Following are the characteristics of the GC gas composition method:

Column: Porapak Q
Gas: Hydrogen with flow rate of 25 ml/min
Oven: 40°C
Detector: TCD at 80 °C and 180 mA

The concentrations of methane and carbon dioxide were calculated using

$$\% \text{ of X} = \frac{(\text{Area of X in Sample})}{(\text{Area of X in Std})} \times (\% \text{ of X in Std})$$

The gas chromatogram obtained is shown in Figure 4. The amounts of CH4, CO2 and CO in the biogas were found to be 59.3 %, 40.6 % and 0.1 % respectively. The biogas compositions from the other digesters were also found to be in the same range.



	Component	Retention Time (min)	Area (mV.s)	Area %
1	CO	2.227	12.667	0.1
2	CO_2	3.223	9133.973	40.6
3	CH_4	7.160	13326.815	59.3
		Total	22473.455	100

Figure 4. Gas chromatogram for the digester DKCF

Conclusion

Kitchen Waste is a very good biogas producer, needs minimal pre-treatment (soaking in NaOH solution and grinding) to enhance the biogas yield. The use of Cow dung with Fungi culture (*Aspergillus Flavus*) for biogas generation therefore, will be a good energy source. The result of the study has shown that anaerobic digestion of ground Kitchen waste with cow dung and *Aspergillus Flavus* improved biogas yield. This performance confirms the earlier reports by other researchers that combining cow dung with fungi culture catalyzes the biogas production with consequent increased yield (Huber, H et. al., 1982)

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Significance of water management plan at mine site & its best practices

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Abstract

The best practice for environmental goal of mine site water management is to protect the environmental values of creeks and other water bodies affected by mining operations. Environmental values, are particular values or uses of the environment that are conducive to public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific water body. A water management plan consistent with best practice must consider and/or develop site-specific standards, targets, operational or contingency plans and procedures. It is reasonable for a community to expect that the nation's mineral reserves will be mined in an ecologically and socially responsible way and that mining operations reflect broader principles of Total Catchment Management. Mine site water management seeks to control or manage various hydrological processes with outcomes that fluctuate randomly. The mine site water balance is managing water volumes and their quality to meet environmental objectives, processing plant needs, and mine development needs over time. Once that is defined, the mine site water balance is the tool used to design the water management system. Monitoring hydrological processes on the mine lease area records the quantitative impact of mining operations on these processes. There are three distinct phases of hydrological monitoring i.e. Baseline, Operational & Post-mining monitoring. Rainfall and Evaporation, Stream flow & Water Quality are the hydrological processes which are monitored on mine sites. Besides monitoring mine site weather and the quantity and quality of surface and groundwater water entering and leaving it, mine management must monitor various parts of the water management system to ensure the system's reliable and auditable operation. Regardless of the best plans, emergencies are likely to arise in operating a mine site water management system. Flood risk management plans are specific to each mine site. During the investigation phase of mine site development, mine site water supply systems should ensure as much water will be recycled as possible. A water quality management sub-plan is an essential part of a mine site water management plan. It is essential to develop an agreed set of performance indicators for the mine site water management plan and the water quality management plan. Such indicators provide an auditable check on the water management system's operation.

Keywords: *Mine Site Water Management Plan, Monitoring, Impact, Best Practices.*

Introduction

A comprehensive planning process is the best way to realize the multiple objectives of a mine site water management plan. The planning process should include in the first instance, adopting a catchment-based approach to mine site water management. This will identify current and potential water management issues in the catchment containing the mine leases, and will assess how mining may aggravate the problems. This approach will ensure mine site water management takes account of catchment issues as well as lease-area ones. Incorporating public consultation to ensure all issues are identified and addressed. Planning is done to address the three phases of mining i.e. development, operation. and de commissioning.

An important best practice for environmental goal of mine site water management is to protect (and if possible enhance) the environmental values of creeks and other water bodies affected by mining operations. Environmental values are particular values or uses of the environment that are conducive to public benefit, welfare, safety or health and that require protection from the effects of pollution, waste discharges and deposits. Several environmental values may be designated for a specific water body. These values are established as part of regional water goals and objectives that consider the ranges of environmental resources, economic opportunities and community preferences. Five environmental values are, 1. Ecosystem Protection; 2. Recreation and Aesthetics; 3. Drinking Water; 3. Agricultural Water & 5. Industrial Water. To determine appropriate environmental values, it is necessary to assess the nature and importance of physical, chemical and biological characteristics of the water body, as well as the role of the water body and its riparian vegetation as habitat for aquatic and terrestrial vegetation and animals.

Recognizing the cost-effectiveness of jointly formulating mine site water management and mine plans. This optimizes coordination of mine site infrastructure and mine site water management measures. Recognizing the most cost-effective solutions to mine site water management issues come from an integrated 'whole of mine' investigation, rather than investigating specific issues in isolation and on an ad hoc basis. A risk management approach to how changing levels of flood, drought and water quality risks should be addressed. A risk management approach to identify and deal with operational risks that generate potentially adverse water management consequences. Undertake appropriate technical studies to adequate standards. Identify and assess a full range of management measures and options. Identify and implement appropriate performance indicators. A water management plan consistent with best practice must consider and/or develop site-specific standards, targets, operational or contingency plans and procedures for all of the following:

Expectations of community

It is reasonable for a community to expect that the nation's mineral reserves will be mined in an ecologically and socially responsible way and that mining operations reflect broader principles of Total Catchment Management. Best practice principles dictate that mine site water management must strive to ensure that during the course of mining, downstream water users and riparian habitats (and their environmental values) are not adversely affected by the impact of mining operations. At the end of mining, appropriate mine site water management measures will be implemented to sustainably protect water quality and preserve water users and riparian habitats downstream. There is effective liaison with stakeholders from areas affected or likely to be affected by mining operations, and that their concerns are addressed. The community is consulted and has access to information, from mine planning stages to mine closure.

Management of risk

Mine site water management seeks to control or manage various hydrological processes with outcomes that fluctuate randomly. Although rare, extreme outcomes can occur with potentially devastating consequences.

The scientific way for managing hydrological risks requires:

1. Recognizing that a formal risk management approach is needed to define appropriate measures and responses.
2. Recognizing the need to evaluate the hydrological event risks and hazards over a full range of event severities.
3. Define the Event of Concern. This may be a flood, a spill of toxic material, heavy rainfalls causing erosion of topsoil before a protective vegetative cover has been established.
4. Evaluate the risk of the Event of Concern occurring. For hydro-meteorological events such as rainfall, runoff, stream flows, etc., this risk can be quantitatively estimated.

For other events, the risk may have to be estimated in qualitative terms such as 'slight', 'moderate', 'high' and 'very high'.
5. Evaluate the hazard associated with the occurrence of the Event of Concern,
6. Formulation of an appropriate Risk Management Plan. The nature and scope of the appropriate risk management measures depends upon the risk of the event occurring and the specifics and seriousness of the hazard.
7. Note that hydro-meteorological events such as storms and floods come in a range of 'sizes', e.g. minor, moderate and major floods. However, the risk of occurrence of 'severe' or 'rare' events is less than the risk of occurrence of 'frequent' events.

Mine site water balance

The mine site water balance is managing water volumes and their quality to meet environmental objectives, processing plant needs, and mine development needs over time. Once that is defined, the mine site water balance is the tool used to design the water management system.

An average annual mine site water balance should be prepared early in the initial investigation phase to identify the average annual shortfall in supply or the average annual volume of excess water generated on the mine site which takes account of seasonal variability of rainfall and evaporation. It also provide a broad framework for more detailed mine site water management studies.

An annual water balance may indicate little about the necessary size of storages or the operation of the mine site water management system. Rather, an annual mine site water balance is an overview of the major sources and destinations of water flows onto, across and off the mine site. More detailed numerical simulation studies are required to size and determine an appropriate mine site water management system.

Monitoring hydrological processes

Monitoring hydrological processes on the mine lease area records the quantitative impact of mining operations on these processes. There are three distinct phases of hydrological monitoring i.e. Baseline, Operational & Post-mining monitoring. The Baseline data provides an invaluable benchmark for measuring the impact of mining operations and any post-mining impacts on hydrological processes. General best practice principles for mine site water monitoring are:

1. Implementing an adequately resourced and well designed baseline monitoring program, ideally starting at least 2 to 3 years before mine development, to get reliable indications of the natural variability of climate and water quality.
2. Adequately supporting and maintaining monitoring programs. Programs and their results need annual review for direction, problems and possible modifications.
3. Selecting reliable equipment with a proven field record.

Typically, the following hydrological processes are monitored on mine sites:

Rainfall and Evaporation

Rainfall monitoring stations need to do more than just record depth and variability of rainfall across the mine site. They need to be distributed in large enough numbers to provide sufficient data for any numerical models proposed for mine site water investigations or for preparing a mine site water management plan. Recording of wind speed and direction, temperature, relative humidity and rainfall is also essential. These parameters make it possible to reliably estimate both evapo transpiration and open water evaporation rates.

Stream flow

To accurately monitor stream flow, mine management should:

1. Site stream flow stations so that they coordinate with rainfall and water quality monitoring sites. In particular, stream flow stations should facilitate calibrating any numerical hydrologic or hydraulic models proposed for the mine site water management plan.
2. Establish at least one 'key' stream gauging station, that is, a site where a current meter can gauge stream flows to determine a reliable rating curve. Identify existing or past official stream gauging stations near the mine lease area.

Water Quality

Water quality monitoring sites are needed at mining lease entry and exit points on all major creeks at risk from mining operations. This allows any change in the quality of stream flows entering and leaving the lease area to be clearly defined. Water quality should be monitored in at least one control catchment not affected by mining. This provides an indication of the 'natural' variation in water quality over the course of mining.

Event-based sampling programs are needed. Runoff events are far more significant than baseline flows for pollutant loads delivered to downstream receiving waters. Appropriate event samplers include pumping water samplers and rising and falling stage water samplers. The latter are robust and less expensive than pumping samplers. Annual water quality reviews are essential. Annual data reports should contain details of any problems with monitoring over the past year. Recognize the importance of biological monitoring programs, as well as the more traditional programs that measure physical and chemical water quality characteristics.

Operational monitoring

Besides monitoring mine site weather and the quantity and quality of surface and groundwater water entering and leaving it, mine management must monitor various parts of the water management system to ensure the system's reliable and auditable operation. This includes the need:

1. To develop and implement an integrated monitoring system that allows the mine site water management system to operated reliably and effectively.
2. To incorporate agreed performance indicators, such as peak water levels in 'dirty' water storages, so system operations can be audited by both mine site and regulatory personnel.
3. To alert mine site personnel to actual or imminent emergencies, eg pipeline rupture, a dirty water dam about to spill, so appropriate response measures are activated.
4. To monitor all major mine site water uses and prepare annual 'water use' reports. On many mine sites, major onsite water uses are poorly defined, eg water volume used for dust suppression, or for ore processing;

Operational monitoring could include flows in key pipelines, water levels and water quality in key storages, especially 'dirty' water storages, mine site rainfalls, silt build-up in silt traps and wetlands, bed and bank erosion in channels. Operational monitoring can be undertaken manually or with automatic equipment. Note, however, that operational data is required for day-to-day and possibly hour-to hour operation of the mine site water management system. It may be necessary to collect key data in 'real-time' and convey them telemetrically to the operational centre.

Emergency monitoring

Regardless of the best plans, emergencies are likely to arise in operating a mine site water management system, eg pipelines may rupture, 'dirty' water storages may spill in an uncontrolled fashion. It is essential that such emergencies are investigated comprehensively to identify the magnitude, impact and circumstances that caused them.
Best practice principles for emergency monitoring should ensure:

1. Each mine has an emergency monitoring plan, i.e. a plan identifying possible emergencies (using risk management) and appropriate monitoring strategies.
2. The emergency monitoring plan addresses the volume, discharge rate and quality of water that 'escaped' and its impact on downstream receiving water bodies.
3. The emergency monitoring plan addresses the possibility of alerting downstream landholders and water users of what has happened and its likely adverse impacts on water supply and/or quality.

Flood risk and hazard

Best practice principles for managing flood risk and flood hazard on mine sites include:

1. Evaluating flood behavior, peak flood discharges and peak flood levels across the mine site for a range of flood events. Such 'flood studies' can be technically demanding.
2. Identifying mine site elements that the various flood events may affect.
3. Evaluating the associated hazard to these elements. Hazard 'seriousness' may range from ‘nuisance’ to economic loss or ultimately, a threat to mine site personnel safety or lives.
4. Developing a comprehensive and appropriate risk management plan for flood hazards. Three broad groups of flood management measures can form part of the plan these are A. Structural works (levees, creek diversions), B. Mine site planning considerations (locating key buildings and infrastructure in less flood-prone areas of the site), C. Emergency measures (flood warning and evacuation plans)

5. Flood risk management plans are specific to each mine site and integrate the three measures stated above. The expected life of mining operations is a key factor in shaping the risk management plan.
6. If the flood risk management plan includes structural works, consider their impact on the downstream habitat and water users.

Water supply

During the investigation phase of mine site development, mine site water supply systems should ensure as much water will be recycled as possible. The feasibility of a joint water supply scheme with another major consumer is assessed. Risks of shortfalls in supply are evaluated and contingency plans prepared to address them. The quality of the proposed source of supply, and need for treatment will also be assessed. The impact of surface storages on the downstream flow regime and habitat and other water users is evaluated. Similarly the risk and consequences of 'dam failure' if applicable must be assessed. The uses, such as for irrigation or recreation of water supply storages at the end of mining are assessed.

Water quality

A water quality management sub-plan is an essential part of a mine site water management plan. It includes:

1. Preparing and implementing a water quality management plan that identifies water quality issues and proposed means of control.
2. Submitting the water quality management sub-plan to regulatory authorities before it is implemented. Separating surface runoff from 'clean' areas of the mine site as effectively as possible from 'dirty' area runoff and from 'dirty' water bodies.
3. Controlling, at source if possible, pollutants or water quality contaminants.
4. Designing and implementing appropriate water quality monitoring programs to measure baseline and operational water quality parameters and appropriate parameters in emergencies.

Performance indicators

It is essential to develop an agreed set of performance indicators for the mine site water management plan and the water quality management plan. Such indicators provide an auditable check on the water management system's operation. When developing performance indicators:

1. Recognize the need to define performance indicators to monitor mine site water management operations and its various components. These indicators need to be agreed to by mine site personnel and regulatory authorities.
2. Prepare annual reports on mine site water management system operations based on these performance indicators.
3. Review operational procedures as and when necessary.

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Water quality and pollution status of Barak River, Southern Assam, India - A Case Study

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Barak river, a vital life line for the people of Barak valley which falls to the southern direction of the state Assam, India. It's the second largest and important river of Assam and Northeast India. Many people are directly or indirectly attached with this Barak river for their livelihood but now the condition of Barak river is so that, it is prone to high levels of pollution and poses serious health hazards to the people of Barak valley. In the river, many carcasses of animal's floats, piles of waste and garbage being dumped on daily basis, direct inlet of refuse besides dirt and filth from Cachar Paper Mill is mixing in the water system.

The worst affected area is Silchar, a major town of Assam. There is a population of around 20,000 from where refuse from open toilets without any drainage or flush out avenues is disposed directly in the river waters. This direct flow to the river and dissolution in it causes direct hazardous water pollution which carries toxic materials and bacterial substances. Around 5 tons of sewerage waste makes its way down the river every month. Just a few meters downstream is the intake point where the Public Health Engineering Department pumps water for its reservoir and treatment plant for water supply to the people of Silchar.

According to survey around 50 tons of waste and pollutants gets discharged in Barak everyday as 8,000 kilo litres of municipal garbage is dumped in the Barak river, resulting in contamination of Barak river and also its very unsafe water for drinking purpose. Moreover farmers use pesticides and insecticides in their agricultural fields for better production of crops which are carried to the river during rainfall also pollute it. Fishery also became a means of living for some section of people of Barak valley and they use chemicals in fish farming or rearing for early growth of the fish which also contribute to the contamination of Barak river water .

Out of date medicines and drugs, other medical items as well as chemical waste from private nursing homes, pathological laboratories, chemists and druggists are also openly dumped into the river waters. Dr. Subijoy Dhar, an American based scientist and a pioneer of Rivers of the World Foundation, who carried out a study-survey as a part of his exploring the quality of water of the river on which millions across the valley depend for their potable water needs. He said that the contamination which is becoming alarming due to burgeoning population along the river system is the cause of several critical diseases including cancer. The volume of oxygen is drastically reduced and Phosphate, mercury contents are on the rise.

The Dissolved Oxygen (DO) Levels in water below 5.0 mg/l puts all aquatic life under stress and the most alarming result is that the river Barak DO level is 2.27 at Panchgram which not only makes consumption of the water hazardous for human health but also a threat to fish and other aquatic species of the river, as studied by Dr. Kumar Kanti Das, President of Exploration Club, a valley based organisation.

Initiatives we can take are to hold mass awareness camps periodically for the people of Barak Valley at critical points where condition of pollution is maximum, especially those who are living near the river and also alerting the district and civic authorities for tougher measures on garbage and waste disposal at Barak valley.