Soil Based Integrated Management Inputs for Flood and Flood Plain Soils of Bihar, India

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Abstract

Flood water is truly a natural resource that supports the production systems through specific management skills. The technical mandate must impose permissible restrictions to its termination to the ocean. To begin with, well defined classical soil survey work should be prioritized as the first step of management options in flood and flood plain soils. Popularly followed flood control as being confined mainly to major civil engineering works alone seems to be insufficient, while flood relief is merely a merciful consolation to the victims. Management is a science that works for truth based on evidences of realities. The target is, thus, to develop an integrated management tool from entry point (dam) to the over flowing stage of river in the surrounding fields through insurance of sustainability in stability and maintenance of river banks. Since such flash floods are predictable as occurring almost periodically, it cannot be a tsunami. Let’s make full utilization of flood water drop by drop, promote for trade of this huge water, fishery production in rivers, inter-linking of rivers and transfer it to drought prone areas. Also, let’s insure the continuity in flow of flood water in a given river on long term basis considering whole river length (origin to termination) as a unit (like Aviral Ganga from Gangotri to Bay of Bengal). The eco-system built-up, hydro-electric plants and river water-ways for transport and tourism are additional opportunities in river basin where entrepreneurial skills can be prioritized and strengthened. Besides, the floodplain soils make ideal situation for second green revolution in Bihar under the scientific umbrella of classical land use planning. A realistic road map following enormous scope of overall development in eco-friendly environment of Bihar could thus be made possible even in flood prone areas.

Keywords: Flood water; natural resource; soil survey; integrated management inputs

Introduction

Excess water beyond the capacity of a river channel is often called the flood water. Let’s not allow such excess water during flood to move to ocean. River basin management must start with detailed soil survey following the conventional or classical tools. To control the bank erosion, keep the susceptible part of a riverbed straight with no bend. The bend angle should be minimized using conservation measures and planting vegetation like Saccharum species. Remote sensing imageries aided with GIS may work as a powerful tool in locating the bend angles including river network. All rivers may be connected selectively on altitudinal basis in order to exploit water resources. Meandering, braiding and ox-bow formation including changing course of rivers are all controllable by reshaping the river banks. Engineering structures are desired to sustain the river beds, which are dynamically affected by direction, flow velocity, depth and volume of river water during flood. The watershed in flood plain is different based on stratified layers of sediments forming soils. Crop calendar in such dynamic landform starting with Saccharum species on sand, a number of small millets, sweet potato, vegetables including cucurbits, fruits like ber, tree like bamboo, acacia and major cereals like maize and wheat, oilseed like sunflower, mustard, linseed, pulses like chick pea, lentil, phaseolus etc in the active flood plain are preferred. Water body in river and ditches are meant for fish culture on commercial...
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basis. Flood plain soils get the salt and many other contaminants washed out and quality production is the key benefits. Keeping land covered with vegetation (conservation agriculture) in pre and post flood periods following zero tillage is additional benefits. Integrated farming including livestock and fishery is made traditionally popular. One of the aspiring proposals towards (i) redistribution of flood water through linking of rivers or other means to drought prone areas and so and (ii) flood water trading to adjoining states or countries must be undertaken on top priority by the Government. There must also be a critical investigation on shrinking trend of water table even in Bihar and possible mitigation approach through excess flood water in hand. Accordingly, the present paper aims at addressing certain alarming issues that call for strategic planning through integrated management inputs as projected for flood and flood plain soils of Bihar, India.

Steps to act and follow ahead

Bihar in India is a museum of rivers, wherein flood is their destiny. Flood water in reality is a natural resource, which is subject to support the production process. Mishra et al (1994, 2001, 2002) and Mishra (2006) characterized floodplain soils [1-4]. The flood and its effective management relate to sediment sequestration and water harvesting as well as ground water recharge [5,6]. Most of the rivers in Bihar, for example, are originating from the Himalaya. The Kosi, for example, moves through Nepal and meet Bihar around Kusaha (Nepal), where there is a dam meant virtually for the safeguard of million of lives, properties, agriculture and overall amenity including livelihood. The maintenance of a dam must be even better than an aeroplane before its take-off. Regular monitoring of satellite data in respect of events causing flood at dam must be mandatory besides enforcing mutual cooperation between Nepal and India. Apprehension about nature and severity of flood may be made possible well before its occurrence using satellite inputs. If the flood is caused by torrential rain continuing for couple of days, its severity may be monitored in terms of management i.e. flood at door. The most vital liability among management options is the clearance of sediments deposited in the river beds. The lifted sediments should be re-deposited on the existing river banks or on the modified re-structured new bank sites in order to keep the direction of river flow straight. For this, delineation of the boundary for river banks requires a survey option using satellite imagery for whole river beds. Following the delineation of river banks, the sediment removal from the river bed is made continued in succession and the loaded sediments are unloaded on the river banks. This process is made continued under some mega project in planned phases to get the desired edged banks of around 100m wide preferably in both sides of the river. To let the Ganges water, for example, flow naturally on long term basis maintaining continuum, Farakka dam needs to be re-structured or shifted elsewhere taking whole Ganga river from Gangotri to Bay of Bengal as a unit.

Mode of Flood

Class I: River with excess water within its capacity.
Class II: River full with excess water following seepage and bank erosion.
Class III: River with overflowing water filling the ditches and Palaeo-channels following intense bank erosion.
Class IV: River with overflow under violent water current causing multiple loses and casualty.

Now, starting from each river side, at least 25 m width of the edged bank should be utilized for plantation of agro-forestry of high photosynthetic demand, whereas sloping side of the bank facing the river water should be packed with boulders and covered with grasses, shrubs and saccharum species (kans) in order to avoid any scope of erosion of the edged bank. Bamboo species are also often planted on each side of the bank.

The agro-forestry (25 m wide) on the edged bank is followed by 40 m wide highways and 35 m wide railways on the same 100 m wide edged bank. The agro-forestry will be cared and maintained by the Forest Department, whereas roadways and railways will be looked into by respective other Departments. Flood Department will be responsible for maintenance of rivers and for clearing the deposited sediments in the river bed according to regular monitoring (preferably in five years) as outlined in the respective planning proposal. Obviously, different Departments would sit together to formulate such mega flood management pilot project in a given river basin of Bihar.

Citation: B B Mishra. “Soil Based Integrated Management Inputs for Flood and Flood Plain Soils of Bihar, India”. EC Agriculture 1.2 (2015): 109-123.
In some cases as in Kosi river basin, the slope gradient is considerably high causing severity in sediment load/deposition in the river bed. In such situation, arrangement may be made to construct the check dams at suitable interval in order to keep the water flow steady at desired velocity in the river bed. While constructing the edged bank with sediments removed from the river bed, care should be taken to keep the distributaries or rivulets undisturbed by making bridges and fly-over for roads and railways. Besides, the removal of silt/sand materials from river beds will expand the river volume tremendously to accommodate the excess water during flood. The river will act as a giant reservoir and restrict water to move to ocean and promote lateral underground movement of water. This is how ground water recharge could be sustained and harmonized on long term basis. The rail and road transport on the river bank may contribute to significant gas emission responsible for climate change. As against this, agro-forestry of high photosynthetic demand along the water bodies (river) would considerably promote carbon sequestration. Such mega project would further facilitate Indian commitment to share in carbon trading significantly in days to come besides harmonizing the regional eco-system in a big way.

Management tips for DAM with four critical components
1. A forecasting wing based on satellite imageries/data: EYES
2. A control, maintenance and monitoring wing: HAND
3. A planning and construction wing: LEGS
4. A set rule to recruit management executives from the local flood affected area: MIND/COMMITMENT

Caring a DAM is like caring an Aeroplane
1. Even a 50 seater aeroplane before takeoff is critically examined and declared fit to the belief of the pilots in order to undertake safe and danger-free flight.
2. Lapses in caring the DAM before flood do cause casualty of thousands of lives and their belongings.
3. Management tips must be followed strictly to escape any sort of uncertainty or danger caused by dam.

River is a huge natural resource for fish culture on commercial basis. Flood management without planning for fishing or fish production is by and large incomplete. Fishery in river water is difficult to manage. However, strategic planning (based on first author’s approximation as well as projection) may facilitate the action plan to be true or close to reality in successful fish production. The managed river bed on its full capacity should be demarcated at a lengthwise interval of 10 km. At each demarcation point, widthwise concrete structure should be made with mechanical arrangement and support to fix metallic nets (preferably of stainless steel) until the maximum water level of the river (based on average). There must be additional arrangement to allow boats and steamers to cross the boundary or compartment in the river, if necessary. Fixing of metallic nets should be such that fishes in one compartment (10 km) may not cross the net. The construction cost would surely be very high at a glance, but production of fishes would encourage such planning and execution through participation. Obviously, such pilot project must be promoted under cooperation through government policy. The commercial fish production would thus run through cooperative societies designed by the regional government in which preference must be given to the adjoining villagers to participate. As explained elsewhere in this chapter, a 10 km long and 250 m wide river in one compartment would cover a water body of 2.5 sq.km area or 250 hectares. At a minimum fish production of 1 to n/hectare/year would yield 250 tons of fishes (250,000 kg) and an average return of Rs. 25 millions (Rs. 2.5 core). Apparently, the projected figures seem to be highly profitable, if efforts should be made in a positive understanding with strong commitment through social participation as well as with entrepreneurial skills. However, technical guidance from Fishery Department is obvious to make necessary correction to such projection. The integrated flood management through structural and non-structural manipulations would thus comprise of the following accomplishments:

a. Regular monitoring of flood events through satellite tools.
b. Maintenance of dam at the entry point and forecasting of severity in time and space.
c. Survey activities to delineate the river flow direction in straight line using satellite imageries by demarcating the altered river banks.
d. Construction of concrete structure with boulders at the delineated acute curvature of river bank using the engineering and mechanical inputs.

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e. Removal of sand/silt materials from river bed and unloading on the demarcated river banks of 100 m on a planned manner.

f. The sloping side of the ridged banks along the river is made stable by using boulders and planting grasses, bushes, shrubs, saccharum species (kans) and even bamboo.

g. The ridged bank should be used for agro-forestry (25 m) followed by highways (40 m) and railways (35 m) with obvious reason as discussed above.

h. Fish production in the managed river compartments having a tentative 10 km length with width wise metallic nets would be an aspiring long term activity fetching good price fishes round the year following their marketing.

i. The cultivable land adjoining the river banks as well as surrounding flood plain areas may be managed as outlined elsewhere.

j. The sand/silt materials of the river bed, after removal, may also be used either in filling the ditches or heavy soil patches (Tal-land) preferably to harmonize the soil productivity for cultivation.

k. Flood plain is characteristic to mixed farming with livestock in Bihar and needs all possible care and maintenance in order to sustain livelihood.

l. Arrangement is desired to link drought prone area, mostly south of the Ganga, with excess flood water by lifting it mechanically in succession from the altitudinal lows to altitudinal highs in order to facilitate irrigation during drought.

m. Perennial rivers may also be used for transport (water ways)

Integrated flood management in Bihar, India thus includes the major activities (figures for measurement are approximation, not yet tested) as below:

a. Satellite message for flood events in Nepal.

b. Maintenance of dam

c. Delineation of river flow direction.

d. Removal of sediments from the river beds.

e. Edging of river banks using removed sediments.

f. Stabilizing the river faced sloppy part of the edged bank.

g. Plantation of agro-forestry on edged bank (25 m).

h. Construction of highways on edged bank (40 m).

i. Installation of railway track on edged bank (35 m).

j. Linking of flood water to drought prone area by mechanical lifting.

k. Fishing in 10 km river apartment by fixing the metallic nets.

l. Cultivation according to land use suitability (market oriented approach)

m. Mixed farming with livestock.

n. Efforts to adopt conservation agriculture/organic farming.

o. Carbon sequestration and trading options.

Characterization of flood plain soils

Floodplain soil, commonly known as active fluvial soil is subject to fluvial action causing settling of sediments followed by depositional equilibrium and pedogenesis. Free survey is conducted to collect information on different management options in floodplains. Specific problems related to bank erosion, watershed development, water harvesting and excess flood water exploitation, land sliding, if any, are identified and their possible solutions are developed as discussed below [7,8,9].

Sediment deposition under the influence of fluvial processes follows the classical laws of physics and chemistry. These sediments on way to develop the soil body undergo depositional regime, polygenic origin, selective distribution of organic carbon, CaCO$_3$ and clay contents, lithologic discontinuity, pedogenic alternation like aggregation and colour change. Chemihydropedoturbation and distribution of selective microorganisms as shown below.
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a. Central concept: Chemihydropedoturbation
b. Highly stratified (organic carbon, clay, CaCO₃ contents)
c. CaCO₃ throughout the profile (if present)
d. Polygenic origin (from different source materials)
e. Depositional regime (after deposition to pedogenic alteration)
f. Selective to crops/plant species (following the mode of siltation/deposition)
g. Soil temperature: river basin eco-system
h. Major group: Diara and Tal land soils
i. Soil colour: gray to white (depending on Fe/Mn and redox state)
j. First pedogenic alteration: boundary followed by mottle/colour change

The active floodplain soils are genetically shown in Figure 1.

Integrated management options

Bank erosion is the most disastrous consequence of the flood [5,6]. Meters and kilometres of land are often submerged within a night with huge personal, social and economic loss and we compare it to that of Tsunami (Figure 2, 3 and 4). The best ways by which the bank erosion could be controlled successfully include the following steps to follow.

Keep the direction of river flow straight

The remotely sensed imageries would help to delineate the path way of river channel and the nature and magnitude of its bending. Geo-referenced imageries may help to locate the point of such bending. At the given point of river bend, it is pre-requisite to measure the degree of river bending. Followed by this is the assessment of soil profiles in respect of their resistance to bank erosion at the given river bending, since the water force exerted by the river flow velocity is tilted towards river bank causing bank erosion.

Survey of soil site around river bend

The sites of a river bend needs to be surveyed for soil type, its vertical depth and stratification. Sand layer in soil profile is very susceptible to erosion. Uniformly distributed clayey or silty layers with sufficient soil depth resist such erosion to the extent that the neighbouring residents may go even to construct big buildings on the bank of river without keeping any doubt of future erosion. Many cities like Bhagalpur, Patna, Delhi, Kanpur, Allahabad, Varanasi, Munger, Buxar are situated on the bank of rivers without any scope of danger from periodic floods (Figure 5). This is because the soil profiles of the respective banks are strong enough to resist land cutting against high water velocity during flood. However, many sites are such where soil profiles are weak due to their textural and structural make-up and so they are very susceptible to bank erosion. The soil survey activities dictate the right way of how to proceed with management or conservation options. Engineering works without conducting soil survey is not only expensive, but incoherent too as long as integrated approach on sustainable management is concerned.

Decision on bending points (curvature) susceptible to bank erosion

Depending upon the slope gradient, depth and volume of river water, its flow direction and velocity, the water forces exerted at the river bend (curvature) finally strike the soil profile to cause erosion. Soil survey could play vital role in making decision on the susceptible nature of soil profile and suitable management option. This is crucial part to be decided for both conservation and management options against bank erosion. River water interacts with soil profiles in both sides depending upon the nature and strength of soil profiles themselves. The bed of the river and the river bending divert the mode and direction of water flow almost towards the river bank causing bank erosion (Figure 6).
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Figure 1: Proposed Fluvisol in USDA Soil Taxonomy (13th Order) for active floodplain soils.

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Figure 2: Strong river flow near the river bank causing erosion.

Figure 3: Severe land cutting of curved river bank.

Figure 4: Terrible situation of bank erosion as affected by stormy water velocity.

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Non-structural conservation (Boulders)

Boulders could accordingly be placed to the site of the river bend or the point, at which the river water has attained maximum velocity to remove sand layers. This approach with boulders may also be followed by plantation of bamboo (*Bambusa bombos*, *Bambusa tulda*, *Bambusa balcooa* and *Bambusa nutans*) and Saccharum species. Where the river morphology is straight without any bend, plantation of bamboo and Saccharum species could keep the sand stabilized for further exploitation of soil resource due to flood. For stabilizing the surface sand layer, kans is very effective (Figure 7).

As such, integrated efforts are desired in the control of bank erosion including conservation with boulders and management with vegetative inputs/strips. Sand is the most common sediment class accessible during flood almost around the main river stream. It is non-coherent to other particles and so susceptible to transportation through fluvial action. In order to stabilize the sand, the option in practice is to plant Saccharum species on sand. During the flood, the bushy Saccharum species reduce the flow velocity of water promoting silt and other fine particles suspended in river water, to settle down over sand. This is a natural practice, but one has to make it necessary to plant and grow such vegetation on sand surface or sand dune. Once the Saccharum species are established, there is practice to grow cucurbits or even sweet potato like suitable crops for economic gain. We need to inventory such crop/plant species suitable

**Figure 5:** Resistant river bank near Bhagalpur of Bihar.

**Figure 6:** Curved river bank and soil profile susceptible to bank erosion.

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suitable to the land through our indigenous knowledge. Water hyacinth and sesbania, for example, are two plant species that may sequester sediments in waterlogged soils.

![Figure 7: Erosion of surface sand layer and stabilization with kans.](image)

Depthwise stratification is a common feature in floodplain soils and is more conspicuous in the soils closed to the main stream of river. However, in heavy textured soils, affected by back water, such stratification is often difficult to identify, since they have the deposits of almost identical type of fine particles (Tal land). In Tal land, the watershed suffers from different problems like low soil permeability, vertic soil features, lime concretion and hard dry consistency.

**Siltation and its possible exploitation**

Siltation in rivers and canals pose special problem. The Kosi River has serious problem of siltation. All irrigation canals under Kosi are badly affected due to siltation. As a control measure, it is theoretically advocated that the velocity of canal water should be slowed down by constructing check dams at suitable interval. Sesbania and Saccharum species may be planted on the canal bed in order to keep the flow velocity within desired level/threshold value (Figure 8 and 9). Other vegetative strips like *Pennisetum purpureum*, *Pannucum coloratum mararikariense*, *Vetiver zizanioides* may also be tested to stabilize the soils in floodplains. Scratching of sand materials is the last resort, though it is practically feasible particularly at the point of its origin.

In keeping the morphology of the river bed stabilized, efforts should be initiated to remove excess silts elsewhere according to their suitability. Most of the present rivers are almost filled with silts/sands and the capacity of river beds to capture water during floods has declined considerably causing submergence of other flood protected areas. This issue must be addressed at policy level in order to keep the perennial rivers continuously flowing without the danger limit of siltation. Same is true with what often talked in case of Aviral Ganga.

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Flood being boon to organic farming

- Undesirable soluble materials being washed through flood (no saline/alkali soil)
- Existing weeds are destroyed or decayed or even removed
- Life cycles of insects/pests are broken and destroyed
- Soil borne diseases partly disappeared
- Deposition of nutrient elements possible
- Soil reaction (pH) being neutral and congenial
- Enrichment of soil moisture

Soil after flood recession as an ideal resource for organic farming.

First vs Second green revolution

The first green revolution was seldom appreciated in the floodplain soils during the period of its inception. However, with the advancement of technology generated in different facets as well as management techniques identified, we are now in a position to look for a better congenial environment coherent to the proposed second green revolution in India even in the floodplain soils (Table 1).
Modern techniques of forecasting particularly through satellites must be kept operational to forecast about the incidence of floods in a particular area. An efficient monitoring of satellite data may warn the people in advance for timely safeguard and rescue operations through volunteer organization as well as government forces. Let the regional and state governments hire agencies to work for flood forecasting well before the incidence of flood violence. Unfortunately, the forecasting system in Bihar is virtually very poor because of its poor connectivity with the agencies. Such slackness or diligence or even negligence towards flood forecast is a blunder that results into disastrous consequences of the flood in Bihar. The degree of damage can surely be minimized following the warning. Once the flood is at door, priority for rescue operations may be fixed following the management principles (EPHADEMAFER) as below (Figure 10).

**Table 1**: Difference between first and second green revolution even in flood plain soils.

**Flood at door**

Modern techniques of forecasting particularly through satellites must be kept operational to forecast about the incidence of floods in a particular area. An efficient monitoring of satellite data may warn the people in advance for timely safeguard and rescue operations through volunteer organization as well as government forces. Let the regional and state governments hire agencies to work for flood forecasting well before the incidence of flood violence. Unfortunately, the forecasting system in Bihar is virtually very poor because of its poor connectivity with the agencies. Such slackness or diligence or even negligence towards flood forecast is a blunder that results into disastrous consequences of the flood in Bihar. The degree of damage can surely be minimized following the warning. Once the flood is at door, priority for rescue operations may be fixed following the management principles (EPHADEMAFER) as below (Figure 10).

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a. Escaping casualty of man and animal by all means (E).
b. Protection of household materials as well as cattle (P).
c. Harvest of matured crops under flood/submergence (H).
d. Accommodation after residential shifting in protected place (A).
e. Deployment of volunteers, army and security personnel to ensure safe displacement and re-placement (D).
f. Enterprise to continue for livelihood security by providing transport/boats (E).
g. Medical facilities to man and animal until return to original place (M).
h. Aids and assistance for survival and farming business (A).
i. Foodstuff and water to the displaced people and cattle (F).
j. Ensuring peace and harmony through cooperation (E) and
k. Restoring ecology and sanitation for healthy environment (R).

Post flood events

When the flood is in hand, there is hue and cry in every affair of the society as well as government depending upon its gravity. The important steps to be taken after the recession of flood event in a given area would consist of the following action plan.

a. Ensure return of men and animals to the original place.
b. Aid and assistance for immediate survival, rehabilitation and enterprise.
c. Restoration of social peace and harmony during rehabilitation.
d. Rejuvenation of distorted rural infrastructure.
e. Medical certification to individual one after preventive measures.
f. Intervention in restoring sanitation and eco-friendly environment.
g. Agricultural inputs to start the farming and maintain animal husbandry.
h. Fish production to be started on commercial basis.
i. Self help groups to help individual person or group.
j. Entrepreneurship among men and women for economic growth.
k. Inventory of damage/losses based on survey.
l. Sensitive factors responsible for missing gaps.
m. International weaknesses and desired partnership for future endeavour.
n. Consciousness towards satellite forecasting about flood incidence.
o. Interdisciplinary panel of experts to review the shortcomings.
p. Formulation of an “Integrated Flood Management Board” with connectivity to agricultural institutes, space and meteorological organizations, land evaluation and land use planning professionals, medical professionals, civil and hydrological engineers, economists, agriculturists, social scientists and cooperative societies.

Entrepreneurship and self help groups

In floodplain area, integrated farming, in which livestock is an integral part with crop production, is an age-old practice that truly ensures farmer’s livelihood. Because of such hidden fact, there is virtually no suicidal case in Bihar due to hunger or even agricultural debt. In fact, there are ample entrepreneurial opportunities in floodplain area other than milk production. It is desirable to create a working environment in the village for self business and cottage industries. The unemployed rural youth could be connected to such small scale business through vocational trainings. There are many small scale business options that can be run through self help groups in the flood affected areas too. It is unfortunate that even for getting a portable small boat, people move to market, though they could have developed entrepreneurial skill to make boats at their doors. Bihar is known to have such huge water resource, but no specific flood water harvest mechanisms are in practice.

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Figure 10: Principles for combating the disastrous flood in hand (EPHADEMAFER).

One of the aspiring proposals towards (i) redistribution of flood water through linking of rivers or other means to drought prone areas and so (ii) hydro-electric plants in selected rivers and (iii) flood water trading to adjoining states or countries must be considered for execution on top priority by the Government. There must also be a critical but detailed investigation on shrinking trend of underground water table even in Bihar and possible mitigation approach through excess flood water in hand. Petrology beneath the soil body might be contributing to lowering of water table and deserves a comprehensive study. Site-specific hydrological mapping is another related priority to be looked into sincerely besides water quality insurance. The action plans to such emerging issues may open enormous opportunities towards healthy livelihood, wherein entrepreneurial skills deserve intervention.

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Microbial Activity
In flooded soil following anaerobic respiration, oxygen is replaced by other compounds as TEA (terminal electron acceptors) like iron, nitrate, sulphate, and manganese, wherein the processes are primarily driven by microbial activity. Flooding alters microbial flora in soil by decreasing the $O_2$ concentration. Fermentation is a major biochemical processes responsible for organic matter decomposition in flooded soils. There are many fermentative bacteria in soils, such as the genus Bacillus, Clostridium, and Lactobacillus with several fermentation products like carbon dioxide, fatty acid, lactic, alcohols getting available in soils and serve as substrates for other anaerobic bacteria. Such low molecular weight compounds produced by fermentation influence the reduction processes of Mn (IV), $SO_4^{2-}$, Fe (III) and $CO_2$ [9].

Nitrate Reducing Bacteria
Mostly obligate respiratory bacteria of genera Agrobacterium, Alcaligenes, Bacillus, Paracoccus denitrificans, Pseudomonas and Thiothrix carry out Denitrification [10]. If oxygen is getting depleted, but nitrate is available, the reduction of $NO_3^-$ to NO, $N_2O$, or even $N_2$ (denitrification) does occur. However, nitrate ammonification is indicated in facultative anaerobic bacteria of genera Bacillus, Citrobacter and Aeromonas or even the members of Enterobacteriaceae [11,12]. Besides, anaerobic bacteria of genus Clostridium are also reported to reduce nitrate to ammonia [13].

Iron/Manganese reducing bacteria
Majority of microorganisms may reduce $Mn^{4+}$ and $Fe^{3+}$. Ferrous iron is used as electron acceptor by iron-reducing bacteria such as Geobacter (Geobacter metallireducens and Geobacter sulfurreducens), Shewanella putrefaciens, Desulfovibrio, Pseudomonas, and Thiobacillus [14]. Bacillus, Geobacter, and Pseudomonas are representative manganese-reducing bacteria. Reduction of ferric oxide may release phosphate and trace elements that are adsorbed to amorphous ferric oxide and thus enhance availability of these compounds in the soil [15].

Sulphate Reducing Bacteria
Sulphate-reducing bacteria such as Desulfbacter, Desulfobulbus, Desulfococcus, Desulfovibrio, Desulfosarcina, Desulfotomaculum, and Desulfonema [16] can use organic compounds as an electron donor and sulphate as an electron acceptor. This reaction for acetate as electron donor is as follows:

$$\text{CH}_3\text{COO}^- + SO_4^{2-} + 3 \text{H}^+ \rightarrow 2\text{CO}_2 + \text{H}_2\text{S} + 2 \text{H}_2\text{O}$$

Wherein some of the sulphate reducing bacteria may oxidize the organic compounds almost completely to $CO_2$.

Greenhouse gas emission
With depletion of oxygen, methane ($CH_4^+$) and nitrous oxide ($N_2O$) are formed as byproducts of anaerobic metabolism in low-redox environment of flooded soils. Carbon dioxide would also form at the interface of anaerobic-aerobic environment following the consumption of methane gas [17]. Matthews and Fung (1987) reported that an estimated 3.6% of terrestrial land is classified as wetlands [18]. Accordingly, the flooded soils with dynamic ecosystems play a significant role in biogeochemical cycling contributing in production of greenhouse gases too.

Conclusion
Flood is a natural resource and so it is in no way a curse, if it is managed precisely on soil based integrated management options as outlined. Let flood be the way of life and livelihood. It also gives numerous income opportunities including fishery, water ways, tourism, water trade and transport in order to promote entrepreneurial skills on way to “Make in India”. The Government should encourage mega projects to attain the goals in the light of emerging vision and mission. Let Bihar be the store house of such huge water resource, if expert persons from across the globe do come forward to mitigate the challenges associated to various events of floods and flood affected soils. A success story of Bihar in such mission would lead the world to formulate a river-specific strategic planning against any apprehension of water crisis in future.

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