POLICY BRIEF

Agroforestry and Farming System Options for Augmenting Productivity and Farmers' Income in the Water Congested Ecologies of the Eastern India

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The Context

The eastern region of India comprising of seven states *viz.* Assam, Bihar, Chhattisgarh, Eastern Uttar Pradesh, Jharkhand, Odisha and West Bengal, occupy about 21.85% geographical area and support 34% human population and 32% livestock population. Agriculture is the mainstay of economy in the region, as 83% population living in rural areas depends on it for their subsistence. On an average, the eastern region has 81.24% marginal farmers, followed by small farmers (11.92%).

Agroforestry as a wide-spread land-use adaptation has potentially supported livelihoods improvement through simultaneous production of food, fodder and firewood as well as mitigation and adaptation to climate change. However, its potential to rehabilitate the wetlands has not been realized in the eastern part of the country for agriculture. In all, the region has 4.05 m ha under wetlands with the highest in West Bengal (1.1 m ha), followed by Assam (0.764 m ha) and Odisha (0.691 m ha). For restoration of these agricultural wetlands, bio-drainage could be one of the potential options besides integrating livestock and fish farming options. In view of the above, it is important to have exclusive management measures and governance mechanisms for the ecologically wet regions of the country, which is here termed as water congested ecologies.

Keeping these in view, a brainstorming session on *"Agroforestry for Rehabilitation of Water Congested Ecologies"* was jointly organized by National Academy of Agricultural Sciences (NAAS), New Delhi and Indian Council of Agricultural Research (ICAR), and hosted by the ICAR Research Complex for Eastern Region (ICAR RCER) in Patna on the 5th of April, 2016. More than 65 lead researchers, scientists, research and extension managers, and policy planners from ICAR institutes and Agricultural Universities of the eastern states, representatives from Department of Agriculture and Cooperation, Govt. of India, World Agroforestry Centre and other CGIAR institutes participated in the session.

The deliberations focused on:

- Issues and strategies for rehabilitation of water congested ecologies,
- Frontier technological options for rehabilitation of water congested ecologies, and
- Roadmap for upscaling sustainable and resilient agricultural technologies for rehabilitation of water congested ecologies.

Based on elaborate discussions amongst the stakeholders, several key recommendations emerged as the way forward for suitable action by the state governments and research organizations in the eastern region that have been summarized here for possible consideration in the process of policy planning measures for promotion of agroforestry and farming system options.

Road map for rehabilitation of water congested ecologies

Tree-based solutions for water congested ecologies

Agroforestry species like *Syzygium cumini, Bischofia javanica, Anthocephalus chinensis, Bombax ceiba, Terminalia arjuna, Tectona grandis*, *Mangifera indica*, *Musa paradisiaca, Eucalytus* spp., etc. were identified suitable for the rehabilitation of waterlogged areas. Subabul (*Leucaena leucocephala*) is however the potential tree-crop for reclamation of saline soils. Makhana (*Euryale ferox*) and underutilized aquatic crops like water chestnut (*Trapa bispinosa)*, sweet flag (*Acorus calamus*) and giant taro (*Alocasia macrorrhiza*) could also be successfully cultivated in the understorey, as it is evident from *Chaur* area of North Bihar.



Farm ecosystem in the water congested ecologies

Multipurpose tree species (MPTs) like *Albizia procera, Terminalia arjuna, Syzygium cumini* and *Dalbergia sissoo* are suitable for plantation in the waterlogged areas of Chhattisgarh, while, species like *Acacia auriculiformis, Terminalia arjuna, Pongamia pinnata, Gmelina arborea* and *Ficus* spp. are recommended for Jharkhand region. Notwithstanding, lac cultivation on *Flemingia semialata*, cultivation of elephant foot yam, colocasia and dioscorea and adoption of agri-horti-silvicultural system have been reported to be ecologically and economically viable as well. Nonetheless, species like *Casuarina equisetifolia* and *Eucalyptus* spp. based agroforestry systems including aquatic crops like water chestnut, makhana and elephant grass (*Typha elephantina)* could prove emphatic in the water-congested coastal ecologies of Odisha and West Bengal.

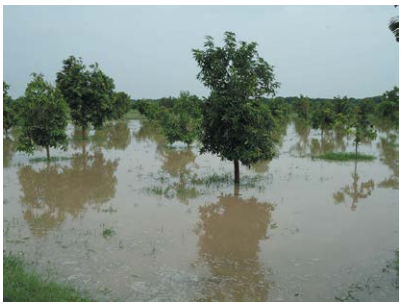
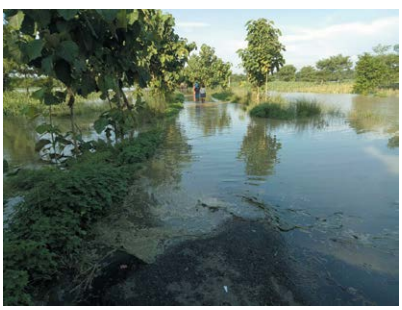
Agroforestry interventions for restoration of water congested ecologies

For reclamation of waterlogged/marshy areas, species like *Flemingia semialata, Terminalia* spp., *Casuarina equisetifolia, Syzygium cumini, Eucalyptus* spp., *Vitex negundo, Salix* spp., *Dalbergia sissoo, Moringa* sp., *Trewia nudiflora, Lagerstroemia* sp., *Anthocephalus chinensis, Mangifera indica* and *Musa paradisiaca* have been recommended as suitable for cultivation under raised bed condition, besides bamboo species like *Bambusa arundinacea*, *B. balcooa*, *B. nutans, Phyllostachys astrovaginata, P. heteroclada*, *P. nidularia* and *Melocanna baccifera*.

A preliminary study by ICAR Research Complex for Eastern Region, Patna revealed highest survival and growth in *A. chinensis*, followed by *Eucalyptus* sp. (Table 1). The tree species could be used under short rotation forestry. On an average, one-third of a hectare, if planted with aforementioned species shall rehabilitate two-third area of the seasonally waterlogged ecologies for cultivation of various agri-horticultural

Table 1. Survival and growth performance of various tree-crops in water congested ecologies after 7 years of plantation

Species	Survival per cent	Tree height (m)	Canopy spread (m)
Anthocephalus chinensis	87.80	15.0±1.8	8.8±1.39
Bombax ceiba	86.63	12.4±1.87	7.5±0.94
Dalbergia sissoo	72.31	8.3±0.89	8.6±1.28
Eucalyptus sp.	72.19	10.5±1.67	6.9±1.12
Ficus hispida	73.14	6.9±0.82	8.6±1.81
Mangifera indica	62.16	5.8±0.76	10.2±1.26
Melia azadirachta	75.39	8.2±0.91	5.8±0.98
Moringa sp.	65.64	5.0±0.63	5.9±0.76
Musa paradisiaca	78.39	3.8±0.17	-
Salix sp.	68.43	5.2±0.73	4.16±0.72
Syzygium cumini	79.47	5.8±0.76	10.4±1.39
Terminalia arjuna	75.68	5.8±0.15	6.9±1.18
T. bellirica	74.83	6.1±0.32	6.8±0.90

Tree integration in the waterlogged areas

crops. This technology would convert excess moisture into biomass and thereby extend profitability to the farmers.

The region, however, suffers from weaknesses such as poor infrastructure like roads and markets, and is challenged with high vulnerability to climate change and natural calamities like floods, submergence, landslides, soil erosion, *etc*. All these have resulted in a low and uncertain agricultural productivity in the region. The low utilization of modern inputs in agriculture has further reduced the ability of the farm households to cope with high risks in production and income.

Agroforestry suitability mapping for water congested ecologies

Waterlogged areas should be mapped and characterized using the available datasets of National Remote Sensing Centre (NRSC) and/or State Remote Sensing Agencies (SRSA) in the eastern region. Further, prognosis of hot spot areas to be put under plantations shall be identified by developing some suitability indices, as this would help in prioritisation of action plans for developing integrated command framework to control waterlogging and salinity. Process based models (like 3-PG) to predict salinity within a given command area/region/basin under the present and afforested conditions would help in afforestation design and highlight management options and priorities. Temporal information on transpiration capacity and hydrological effectiveness with high-density bioenergy plantations of selected salt-tolerant species also need to be generated for inclusive mapping. All these, if done, shall enable successful establishment of agroforestry systems by providing ideal directions and tree spacing needed to minimize its adverse impact on understorey crops in a given farm-setting.

Field gene bank for water congested ecologies

Inter-institutional collaboration for maintaining germplasm of different fodder crops, agroforestry species and bamboo species, which can survive in the water congested ecology. Additionally, tree arboretum and field gene banking of waterlogging tolerant fodder species are also essentially recommended for the eastern India. For instance, para grass (*Brachiaria mutica*), common reed grass *(Phragmites australis)*, karnal grass (*Leptochloa fusca*) and signal grass (*Brachiaria brizantha*) could be cultivated in prolonged stagnant waterlogged areas. Similarly, *Paspalum notatum,* and Teosinte (*Euchlena mexicana*) shall be raised in occasional or seasonal waterlogged areas. Likewise, farmers' innovations on management of waterlogged area, like floating vegetable fields of Assam could be replicated in other parts of eastern India too.

MSP for forestry/agroforestry products

Policy guidelines for enabling minimum support price (MSP) for various forestry/agroforestry products and also a framework for biodrainage are the need of the hour. Perhaps, this is applicable for the country as a whole. This could be done through an Inter-Ministerial Task force, as enabled by the Ministry of Agriculture and Farmers' Welfare, Govt. of India.

System approach for management of water congested ecologies

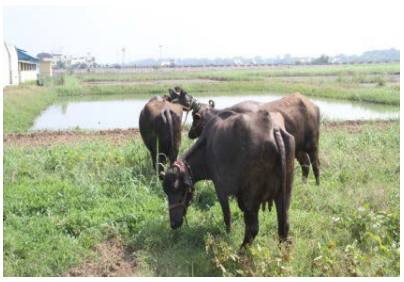
Horizontal expansion of rice-fish integration along with seasonal vegetables like bottle gourd, okra, cabbage, cauliflower, french bean and cowpea have tremendous potential in the eastern region, particularly in water congested ecologies. In *kharif*, rice as a mixed cropping system could be a better option for water congested ecologies.

Rice is usually broadcasted with mungbean, sesame, fodder sorghum, jute, *etc* in summer. Such mixed cropping system induces a fair degree of sustainability even if the rice fails. The mixed crops are harvested before the floods in June-July. Yields as high as 4 t/ha could be achieved with rice + mung bean and rice + jute, as recorded in the Kosi command area of Bihar, where investments have been virtually nil. Flood tolerant rice varieties like Swarna Sub1, Samba Mashuri Sub1 and IR64 Sub1 can be grown in areas, which are frequently affected by flash floods, and causes 10-15 days inundation.

In low lying areas that is expected to have water stagnation up to 15th October every year and the fields continue to be remain wet during October-November, sowing of wheat or lentil during *rabi* may be taken up as *utera* cropping (broadcasting of seeds in standing rice 10-12 days before rice harvest), or with the help of Zero Tillage (ZT) machines. Evidently, resource conservation technologies (RCTs) have a great significance in increasing the productivity of rice-wheat cropping system in the eastern India.

For effective utilization of lowland ecosystems (popularly known as *Tal*, *Khal*, *Jheels*, *Beels*), raised bed-pond system or raised bed-flat bed-pond system of cultivation can successfully alleviate the problem of drainage congestion in monsoon and mitigates water





Livestock-fish based integrations for water congested ecologies

scarcity in dry season where nothing could be grown due to poor drainage, flash flood, occasional flood and land submergence. The land configuration in this system can increase the opportunity of employment as well as supplement protein and fat requirements of marginal and disadvantageous farmers. For scientific fish cultivation/aquaculture in the low lying areas, where water recedes in about 4-6 months (particularly in West Champaran, East Champaran and Muzaffarpur districts of Bihar), there is a need to build check dams and pump ground water into the pond to ensure that level of water does not decrease and potential fish yield is harvested. Notwithstanding, there is also vast scope to construct tanks and a canal system in flood-prone areas of eastern region for commercial fish farming. Further, upscaling of rice-fish cultivation together with agroforestry as in Chhattisgarh, and farming systems approach with pig or goat as in Jharkhand should be considered in all government programs targeting sustainability of livelihoods of the indigenous communities.

The experiments conducted by ICAR Research Complex for Eastern Region, Patna have proved that fish productivity could increase manifolds when integrated with livestock/birds compared to fishery alone, *i.e.*, fish rearing without integration (Table 2). In addition, the successful models of cage and pen culture suitable for the water congested ecologies shall be promoted.

Table 2. Fish productivity in farm integrations

Integration	Productivity (t/ha)
Fish-duck	3.80
Fish-poultry	3.56
Fish-goat	2.90
Fish-pig	3.90
Fish-cattle	5.50
Fish-buffalo	5.30
Fishery without integration	0.76

IFS for doubling of farmer's income in the water congested ecologies

Integrated farming system (IFS) is the viable option in order to achieve food and nutritional security at household level in the area particularly dominated by small and marginal farmers. Such land use system could provide round the year production and income to the farming family.

A 2-acre IFS model developed by the ICAR Research Complex for Eastern Region, Patna for the lowland and midland irrigated ecosystems of Bihar gave some insights into the efficacy of this system benefiting the marginal farmers, both in terms of production and income. In this model, crop-livestock-fishery was integrated with allied enterprises like duck farming and vermicomposting, and food crops (*kharif* rice, followed by *rabi* wheat, maize, lentil, mustard), fruits and vegetables. The model gave a net monetary gain of Rs. 1,37,000/- per year. Likewise, 1-acre model integrating agri-horticultural crops, goat, poultry with allied enterprises like vegetables, mushroom and vermicomposting gave a net monetary gain of Rs. 79,500/- per year. These successful models deserve upscaling in the entire region.

IFS model for round the year fodder production system was also developed to sustain livestock component across seasons. For example, multicut sudan grass, cowpea, maize and bajra could be grown during rainy season whereas, berseem and oat during winter season. It is estimated that total biomass production of 66.0 t could be obtained from 1 acre area, which would sustain 9 milching cattle (or) 6 milching buffalo (or) 73 Black Bengal goats in Indo-Gangetic Plains of eastern India (Table 3).

Other successful integrations such as rice-fish-azolla, rice-fish-pig, rice-poultry-duck, rice-fish-goat and rice-fish-cattle/buffaloes shall be promoted for farming system development in the water congested areas of the eastern region.

Table 3. Season-wise production of various fodders

Season	Fodder type	Total yield (t/acre)	Dry matter yield t/acre)
Summer	Multicut Sudan	29.91	5.80
Rainy	Single cut Sudan/ cowpea/maize/bajra	8.95	2.01
Winter	Berseem/oat or mixed farming of both	27.14	4.66
Total		66.00	12.47

Salient research observations on water congested ecology

While the water-congested ecologies have unique characters to transform its potential to produce important crops, crop combinations, integrated approach for maximizing its production and productivity potentials, there are some suggestive measures that have been tested in selected fields and could possibly be adopted for increasing the water use potential in these challenging areas, which have been narrated below.

- Prolonged waterlogging (> 1m surface waterlogging) during rainy season in some parts of the region reduced tillering and growth of normal rice varieties. Sometimes flash flood inundates the standing crop at any stage of growth for 8-10 days at a stretch, resulting in heavy mortality. The crop is damaged completely if this occurs at early vegetative stage. Hence, proper establishment of crops before onset of flooding and adoption of deep waterlogging tolerant rice varieties (Hangseswari, Saraswati, Ambika, and Sabita) are of paramount importance to realize higher net returns from the crop. These varieties could produce 2.4-2.5 t/ha yield in *kharif* season in deep waterlogged situation with cost of cultivation of Rs. 10,000/ha.
- Due to poor drainage, saucer shaped topography and high monsoon rainfall, some parts of Eastern India remain waterlogged (> 1m) and unproductive. To stabilize and enhance net income from such areas, pond based farming technology (deep water rice in *kharif* + vegetables like watermelon, ladies finger, spinach, chili in winter + fruits + fish) could be adopted. An additional income of Rs. 25,000/ha/annum with water productivity of Rs. 7.2/m^3 could be realized adopting the technology.
- In the seasonally water logged areas, makhana is cultivated in a cropping system mode (water depth- up to 0.60 m). While 4-5 months are sufficient for makhana cultivation, other crops could be cultivated successfully from the same piece of land. Makhana yield in cropping system mode has been recorded @ 2.8 t/ha compared to 1.6 t/ha in perennial/seasonal water bodies. Field method of cultivation requires less water for makhana cultivation. Makhana could be transplanted in the second week of April and harvested by the second week of August. Short duration varieties of rice could be cultivated thereafter. Sequentially, fodder crops could be sown by mid of December and harvested by the second week of April. Hence, cultivation of three crops per year is possible in such areas, particularly in Darbhanga, Madhubani, Samastipur, Sitamarhi, Araria, Saharsa, Madhepura, Supaul, Purnea and Katihar districts of Bihar.
- Cultivation of makhana with fish and water chestnut has been proven suitable for the waterlogged districts of Bihar. It includes cleaning of pond before emergence of makhana seedlings, removal of carnivorous fishes by application of *mahua* oil cake @ 2.5 t/ha, transplanting and gap filling of makhana, making refuge area of 10% of total water body area and integration of different carp fingerlings. Water chestnut is cultivated as a tertiary crop. The net monetary return for such system has been estimated to be Rs. 88,910/- per ha. It is envisaged that the technology has a potential for adoption in 1.10 M ha of non-arable waterlogged areas in the country.
- The possibility of pasture-goat integration was also explored in seasonally waterlogged areas. For instance, the waterlogged area with water depth of 0.5-1.0 m for 3-5 months was converted into alternate trenches (1.5-2.0 m depth) and the so excavated soil was used for bed preparation for pasture production. On the bed, leguminous and non-leguminous grasses were planted. Fifteen Black Bengal breed of goats were integrated with the system and in trenches fish fingerlings were stocked. With this kind of integration, about 82.0 t/ha fodder, 90 kg meat/ha/year and a total of 2.2 t/ha fish were produced that manifested an additional income of Rs. 49,600/ha/year that can be realized with cost of cultivation of Rs. 57,000/ha.
- The fresh water, which floats above the saline water below ground in coastal water logged areas, could be tapped through subsurface water harvesting structures to meet the *rabi* crops irrigation requirement as well as pisciculture. To extract water from these structures, pump sets

up to 2 hp has been found suitable to avoid saline water ingression into fresh water layer. The depth of structure should however be restricted within sandy zone below ground up to 5 m. According to an estimate, the average water productivity of sub-surface water harvesting (SSWH) involving pisciculture and *rabi* vegetables is Rs. 36/m^3 with a unit cost of Rs. 14/m^3. It results in higher area of irrigation including higher cropping intensity and crop productivity. The average benefit:cost ratio of SSWH was reported to be 1.55 in the first year of construction itself. The participatory approach of implementing sub-surface water harvesting could further improve the economic status of resource poor farmers inhabiting in the waterlogged areas.

Convergence of various National Programmes and Schemes for Effective Management of Water Congested Ecologies

National Missions such as National Water Mission, National Mission for a Green India, National Mission for Sustainable Agriculture, National Horticulture Mission, National Bamboo Mission; Sub-Mission on Agroforestry, National Food Security Mission, National Rural Livelihood Mission and programmes such as MNREGS, Rashtriya Krishi Vikas Yojana, Compensatory Afforestation Fund, National Project on Organic Farming, Micro Irrigation Scheme, National Project on Management of Soil Health & Fertility, all have component of tree plantations, silvipasture, planting fertilizer (Nitrogen-fixing) trees/shrubs. These programmes can easily be extended to the eastern India for promotion and adoption of agroforestry and integrated farming systems in the water-congested ecologies.

It is worth-mentioning that after the launch of National Agroforestry Policy (2014), 27 states have relaxed felling, transit and processing regulations for agroforestry trees which is a good step forward. Also, Govt. of India amended the Indian Forest Act, 1927, exempting bamboo grown in non-forest areas from felling or transit permit facilitating bamboo as agroforestry component in small landholders reach.

For instance in Bihar alone, 10 species have been exempted from the purview of Transit Rule vide Notification No. Van Vikraya.38-2000-456 dated 27.02.2009. The exempted species include poplar, eucalyptus, kadamb, gumhar, mango, litchi, tar, khajoor, semal and bamboo except giant bamboo (*Dendrocalamus strictus*). Recently, the following 17 species as well as a few imported timber of species not found in the state were added to the earlier list of ten species exemption from the purview of Transit Rule through Bihar Timber and other forest produce (Regulation of Transit) (Amendment) Rules, 2017. The species are- Israili babul (*Acacia tortilis*), Vilaiti babul (*Prosopis juliflora*), gulmohar (*Delonix regia*), ber (*Ziziphus jujube*), amrud (*Psidium guajava*), Mithi neem (*Murraya koenigii*), Jacaranda (*Jacaranda mimosifolia*), subabul (*Leucaena leucocephala*), shahtut (*Morus alba*), ashok (*Polyalthia longifolia*, *Saraca indica*), casuarina (*Casuarina equisetifolia*), Silver oak (*Grevillea robusta*), palm (*Palm* spp.), nimbu, santra, mosambi (*Citrus* spp.) peltoforum (*Peltophorum ferrugineum*) rubbar (*Ficus elastica*) and rimjha /safed babul (*Acacia leucophloea*). So far, 20 districts of the state (Aurangabad, Begusarai, Bhagalpur, Bhojpur, Buxar, Gopalganj, Jehanabad, Katihar, Khagaria, Madhepura, Muzaffarpur, Nalanda, Patna, Purbi Champaran, Purnea, Saharsa, Saran, Sheikhpura, Siwan and Vaishali) have been covered under the sub-mission on agroforestry under the National Mission on Sustainable Agriculture.



Cage and pen culture, and floating horticulture for leafy vegetables in water congested ecologies

Key Discussants

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- O.P. Chaturvedi, Director, ICAR-CARI, Jhansi, UP
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- P.S. Minhas, Former Director, ICAR-NIASM, Malegoan, Baramati
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The viewpoints and inputs during the brainstorming session formed the basis of this policy brief, for which the key discussants are thankfully acknowledged.

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Citation: Bhatt, B.P., Arunachalam, A. and Mishra, J.S. (2020). *Agroforestry and Farming System Options for Augmenting Productivity and Farmers' Income in the Water Congested Ecologies of the Eastern India*. Policy Brief, 8 p. Indian Council of Agricultural Research and National Academy of Agricultural Sciences, New Delhi