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Use of Water Hyacinth for Adaptation to Climate Change in Agriculture in Bangladesh

Anusree Ghosh[1*], Tapas Ranjan Chakraborty[2]

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ABSTRACT

Bangladesh is a land of wetland, and the country's main livelihood option is agriculture. Due to climate change, agriculture is being interfered with because of different diverse situations. The agriculture here is mostly rainfed and uses available resources to meet the farming requirements. Water Hyacinth (*Pontederia crassipes*) has a wide range of uses in agriculture, like, cultivation in floating bed, mulching, germinating seeds, and dividing lands, etc. The use pattern is very much localized. The community is using those traditional farming practices as adaptation technology since climate change vulnerabilities are increasing. The development intervention also amplifies the use spectrum. Findings of 25 consultations with communities country-wide, conducted between June 2019 to January 2020, stated that the water hyacinth could be a good option in climate adaptation action in agriculture. It was found that the techniques also have a number of forms based on geo-cultural character. The water hyacinth is used to cope with floods, water logging, drought and salinity. The study also found that the transformation of the technologies is not that significant to adapt to the local ecosystem. The promotion of local knowledge and technologies needs proper documentation and adoption while introducing a new ecosystem. Since water hyacinth-based farming technologies are low-cost and affordable by the farmers and national policies are committed to climate change adaptation, promotion of this technology needs to be locally adopted. Following the national climate adaptation strategies, the use patterns and technologies of water-hyacinth must be local ecosystem specific in a way that it will not interfere the environmental wellbeing and also strengthen the practice of indigenous knowledge. Knowledge management is also a requirement of climate adaptation technology promotion.

INTRODUCTION

Bangladesh is recognized worldwide as one of the countries most vulnerable to the impacts of global warming and climate change. This is a wetland land located in the lower part of the basins of three great rivers of the world- the Ganges, the Brahmaputra and the Meghna. These rivers' floodplains and numerous tributaries and distributaries cover about 80 percent of the country. As a result of the flat topography of the floodplain, one-fifth to one-third of the country is annually flooded by overflowing rivers during monsoon, from June to September. Sudden, severe and catastrophic floods have intensified and are taking place more frequent. Bangladesh has been ravaged by floods of catastrophic proportions, in 1998, 2004, 2007, 2010, 2012, 2013, 2017, 2022 and 2024. The people and social system have knowledge and experience of coping with the calamities. The country's main livelihood option is agriculture. Traditional agriculture practice is subject to nature's well-being. The community themselves have adapted with the flood to some degree and extent. There are a number of traditional adaptation practices in agriculture. Water hyacinth, *Pontederia crassipes*, has wide use in traditional farming, which is now being used by the community as adaptation technology to climate change and has potential in Community-based Adaptation and Local Adaptation. There are traditional uses of water hyacinths country-wide. Since the availability of water hyacinths are comparative more in the southwest 'Beel' basin and northwest 'Haor' basin compering with other areas of the country there are good number of planned adaptation interventions from different projects in those two areas. The National Adaptation Plan of Bangladesh (2023-2050) suggested aggregation of water hyacinth for reducing heat stress in signifying adaptation priorities related to fisheries and aquaculture (GoB, 2022). The national plan also recommended Upscaling of floating agriculture for the southern, haor and beel areas. Bangladesh Climate Change Strategy and Action Plan 2009 (MoEF, 2009), which is a living document has programmes for development of climate resilient cropping systems. The Water hyacinth is being used as a means of adaptation to climate change in agriculture in different ways. In most cases the use-form is traditional but also blended with modern adaptation technologies. The study has documented those practices and has explored the potential as a climate change adaptation action.

MATERIALS AND METHODS

To understand the diversity of the use of water hyacinths in agriculture for adaptation to climate change the study was conducted in most climate vulnerable location of

[1] Department of Agricultural Science, School of Education, Bangladesh Open University, Gazipur, Bangladesh
[2] Climate Change Programme, BRAC, Bangladesh
[*] Corresponding author's e-mail: anusreeghosh62@gmail.com

the country. There were semi-structured community consultations conducted. In the consultations the participants share knowledge, perception and practice in relation to the local climate change and impact. In the consultations there were no interference from the authors but keeping discussion on tract was carefully done. There were discussions on climate change adaptation practices. The consultations focused on

• Changes in temperature, rainfall patterns and extreme events;

• Impact of those changes in crops cultivation and production;

• Adaptation measures taken by community traditionally and or planned by development intervention by Government and Development Sectors;

• Detail of the Technology if based on Water Hyacinth.

If the community had any form of water hyacinth use practice in agriculture and implication of this traditional practice had been increased due to address the extreme climatic event the field practice was observed and documented in detail. Those consultations were conducted between June 2019 to January 2020 in Barisal, Bhola, Brahmanbaria, Chandpur, Cox's Bazar, Cumilla, Faridpur, Gopalganj, Habiganj, Khulna, Kurigram, Mouvibazar, Naogaon, Natore, Netrokuna, Nilphamari, Noakhali, Sunamganj and Sylhet districts. The identification of those districts was done by exploring the climate vulnerability index of districts done in the Final Draft Report of Nationwide Climate Vulnerability Assessment (MoEFCC, 2018). In this assessment the volubility indexes were, People Affected Due to Natural Disaster, Heat Stress, Ground Water Quality, Depletion and Degradation, Mangrove Forest Vulnerability, Land Availabilty for Livestock, Water Availability, Crop Yield Vulnerability, Decrease in Livestock & Poultry Health Vulnerability, Land Availability for Agriculture, Change in Fish Culture, Change in Fish Capture, Rail Network Vulnerability, Road Network Vulnerability. The local uses of water hyacinths were observed to know the technology in detail and also the origin of the knowledge were explored. The Nationwide Climate Vulnerability Assessment has identified six vulnerable areas, viz., Central flood-prone area, Northwest drought-prone area, Southern coastal areas, Northeast Haor basin, Eastern hilly region, Urban areas. The current study was not able to cover the Eastern hilly region.

The findings in the current paper are based on 25 community consultations that were semi-structured and were conducted countrywide. Most of the community consultations were conducted with the farmers in the crop field, a few were conducted in market places but with farmers. The number of participants were from 6 to 11 in a consultation. The study has not covered the hilly areas of the country, there may be some different form of water hyacinths use in agriculture.

RESULTS AND DISCUSSION

Climate Change and Its Impact in Agriculture

According to the farmers the changes in rainfall pattern is very specific. There is huge rainfall in the early monsoon and in the closing of the monsoon nowadays which was a monsoon long regular rainfall even only two decades ago. There was huge rainfall in a short time which did not happen earlier. Also, the form of week-long rainy days which was known locally as "Badla" or "Badol Din" was not observed from the end of the first decade of this century. According to the farmers, the main climatic threat is the changed pattern of rainfall. The changes in the seasonal calendar are clear and visible. More fog is a new threat to agriculture. There was salinity in soil and water in the coastal crop field. Evidence of localized drought in very small areas in a scattered distribution was common. There were heat waves and cold waves and floods were frequent in some areas. The use of water hyacinths is mostly to keep the moisture of the soil.

Technologies

Water Hyacinth has a wide form of use in crop framing that varies from place to place. The use of Water Hyacinth is mostly to cope with flood, drought and salinity. The local farming technologies based on water hyacinth are as follows:

Baira

'Baira' is a form of hydroponics practiced in the north eastern districts of Bangladesh. 'Baira' is a platform of rotted water hyacinth. It is used as a seed bed and for cultivation of different crops, especially the vegetables. It was recorded that 26 crops are cultivated in Baira in Gopalganj area.

'Baira' preparation mostly starts in May-July. However, in areas where winter vegetable cultivation is the main purpose of Baira farming, Baira preparation starts as late as September. The preparation time is dependent on the availability and the maturity of the water hyacinth. About 60 days are required for water hyacinth to be matured and the two-month-old plants are appropriate for making a 'Baira'. 'Baira' could also be made from immature plants, but in that case the floating platform will not be strong and compact enough. Water depth is not a crucial factor for preparing Baira. Though water hyacinth is the main material, Durali (*Hygroryza aristata*) is used to make pot for the seeds. Water lettuce (*Pistia stratiotes*), Duckweed (*Lemna sp*), *Hydrilla verticillata.* and *Salvinia* sp. are also used for this purpose.

There are two forms of Baira. One is comparatively smaller in size found in Gopalganj district and the other form is quite large available in Barisal and Pirojpur. The Baira is also called as Dhap and Gatua. The word Dhap is very common in Pirojpur areas. The preparation and cultivation process in Baira at Chanda Beel of Gopalganj is as follows: At the beginning, a long bamboo is horizontally placed on the floating bulk of mature water hyacinth along the desired length of the Baira. A person by standing on the bamboo piles up water hyacinths on both sides of the bamboo and subsequently flatten the plants under his feet. This process continues along the bamboo until

the bed reaches the desired length, breadth and height. After a week or so, water hyacinth is further dumped on the already prepared floating bed. In Gopalganj area the common size of a 'Baira' is around 15 meter long, 2 to 2.5 meter wide and 0.7 to 1 meter height. For a 0.7 to 1 meter height 'Baira' it is necessary to dump water hyacinth for 2 meters height (Table 1). It normally takes 15 to 30 days for water hyacinths of a platform to be rot. After placing a 'Baira' in the desired place, farmers often anchor bamboo poles to stop the platform from floating away.

Table 1: Change in dimension of 'Baira' platform over time

Time	Length (meter)	Wide (meter)	Height (meter)	Weight (Kg)
During preparation	11	2.8	2	930
20 Days	10.5	2.5	1.5	750
4 months	10	2	1.2	560
in drained out condition	9	1.5	0.6	180

Cultivation in 'Baira' Platforms

'Baira' farming includes raising seedling as well as cultivating vegetables. For the germination of seeds the seeds are kept in pot like seed germination structure which is locally called as Guti. The Guti is made from aquatic creeping grass Durali (*Hygroryza aristat*) and Salvina sp. The 'Guti' acts as container to hold the seedling. To make a 'Guti' the Durali plants are dried in the sun for 3-4 days. Before making a 'Guti' water is drayed on the dried plants to soften. There is no definite size of 'Guti' but around 2 meters long 'Durali' is used in a Guti. The wet seeds are inserted in the 'Guti' with some rotten water hyacinth mostly the root of hyacinth. In general, 2 to 3 seeds are putted in a 'Guti'. The Gutis are then pilled in a shed or in a shady place for 3-4 days. After that the Gutis are spread on the open ground to allow germination. The seed starts to germinate after 5th days. After 9-10 days when the seedling attains 15-18 cm the Gutis are transfer to 'Baira'. The distance between Gutis is preferably 20 cm. Twenty-six species of crops were recorded cultivated in Baira Table2

Table 2: Crops cultivated on 'Baira' at Gopalganj

Sl	Local Name	English Name	Scientific Name (Family)	Season
1	Ada	Ginger	*Zingiber officinle* (Zingibaraceae)	Summer
2	Badhakopi	Cabbage	*Brassica capitata var. oleracea* (Brassicaceae)	Winter
3	Barbati	Cowpea	*Vigna sinensis* (Papiliaceae)	Winter
4	Begun	Eggplant	*Solanum melongena* (Solanaceae)	Summer Winter
5	Chal kumra	Wax gourd	*Benincasa hispida* (Cucurbitaceae)	Summer
6	Dhan	Rice	*Oryza Sativa* (Poaceae)	Winter
7	Dhaniya	Coriander	*Coriandrum sativum* (Apiceae)	Winter
8	Dheras	Ladies Finger	*Abelmoschus esculentus* (Malveceae)	Summer
9	Dhundal	Sponge Luffa	*Luffa cylindrica* (Cucurbitaceae)	Summer
10	Fulkapi	Cauliflower	*Brassica capitata var. botrytis* (Brassicaceae)	Summer
11	Gajor	Carrot	*Daucas carota* (Apiaceae)	winter
12	Holud	Turmeric	*Curcuma longa* (Zingiberaceae)	Summer
13	Kochu /Mukhi	Taro	*Colocasia esculenta* (Areceae)	Summer
14	Lalshak	Red amaranth	*Amarenthus tricolor* (Amaranthaceae)	Summer/ Winter
15	Data	Stem amaranth	*Amarenthus tricolor* (Amaranthaceae)	Summer/ Winter
16	Lau	Bottle gourd	*Lageneria siceraria* (Cucurbitaceae)	Winter
17	Mistikumra	Pumpkin	*Cucurbita maxima* (Cucurbitaceae)	Summer
18	Morich	Chilli	*Capicum frutescens* (Solanaceae)	Summer
19	Mula	Radish	*Raphanus sativus* (Brasicaceae)	Winter
20	Olkapi	Kohlrabi	*Brassica oleracea var. gongylodes* (Brassicaceae)	Winter
21	Paat	Jute	*Corchorus capsularies* (Tiliaceae)	Summer
22	Palongshak	Spinach	*Spinacea oleracea* (Chenopodiaceae)	Summer
23	Puishak	Indian Spinach	*Basella alba* (Basellaceae)	Summer/ Winter
24	Shalgam	Beet	*Brassica campestris* (Brassicaceae)	Winter
25	Shim	Hyacinth bean	*Lablab purpureus* (Papilionaceae)	Winter
26	Tomato	Tomato	*Lycopersicon esculentum* (Solanaceae)	Winter

The size of 'Baira' varies with the availability of the raw materials, i.e., the water hyacinths and other environmental factors, like wave action, space availability, and local land use pattern and social practice etc. The material for 'Guti' also varies on availability. The difference between the 'Baira' found in Gopalganj and Barisal is noted in the Table 3 bellow:

Table 3: Difference between 'Baira' cultivation in Gopalganj and Barisal-Pirujpur

	Barisal-Pirojpur	**Gopalganj**
1. Beginning Season	End of May	End of June
2. Length	30-60 meter	9-10 meter
3. Width	0.6-1 meter	2.7-3 meter
4. Crops produced	4 times	2-3 times
5. Guti is preparation by	Indurkani pana (*Salvina* sp.)	Durali (*Hygroryza aristat*)
6. Distance between two Gutis	Not fixed	~20 centimeter

The indigenous distribution of 'Baira' was from limited in the calm wetlands. To reduce the wave actions affecting the 'Baira' in the Chanda beel areas of Gopalganj District cultivation of Daincha (*Sesbania bispinos*) were found. Though Daincha was cultivated for fuel wood but farmers also recognized their importance on wave action reduction.

Bhasan Chas

'Bhasan Chas' is practiced in Matlab and Haimchar areas. The lowlands of this area remain under the standing flood water for a long time in monsoon that agitates cultivation of late summer crop and makes the winter cultivation late. The community is practicing 'Bhasan Chas' to start cultivation in time. The farmers take preparation for the 'Bhasan Chas' from late June.

Preparation of Bhasan

The farmers store water hyacinths in a half meter diameter and make a stack of around one meter height. The base is wider than the top. There is no hard and fast role of stacking, the process is simple damping of water hyacinths. According to the farmers, putting the hyacinth by keeping the root upside down and in the periphery takes comparatively little time to decompose. The height of a decomposed dome is around half meter. The stack is commonly called as 'Dom' or 'Dhomba'. The farmers usually keep a 50-80 cm distance between two Doms. The farmers put some soil rich with fertilizer on the Dom and plant seeds on it. 'Bhasan chas' is not practiced as seed bed like Baira; the germinated plants grow up on the Dom and when the flood water dried up the root system of the plant goes to the top soil of the field. Total decomposition of the hyacinths on Dome is not necessary for planting on Dom. After the harvesting the residue of the Dom is used as organic fertilizer. It was found that in Haimchar areas the 'Bhasan Chas' advanced cultivation of vegetables by 2 months. If a farmer wants to cultivate the winter crops after the monsoon he has to wait until the flood water dried up or ran out totally. Fruit crops and the leafy vegetables are mostly cultivated in the process of 'Bhasan Chas'. The most common vegetable cultivated in the 'Bhasan Chas' are as follows:

Table 4: Crops cultivated on Bhasan Chas at Matlab

Sl	**Local Name**	**English Name**	**Scientific Name (Family)**
1	Begun	Eggplant	*Solanum melongena* (Solanaceae)
2	Lalshak	Red amaranth	*Amarenthus tricolor* (Amaranthaceae)
3	Lau	Bottle gourd	*Lageneria siceraria* (Cucurbitaceae)
4	Mistikumra	Pumpkin	*Cucurbita maxima* (Cucurbitaceae)
5	Puishak	Indian Spinach	*Basella alba* (Basellaceae)
6	Shim	Hyacinth bean	*Lablab purpureus* (Papilionaceae)
7	Korala	Bitter gourd	*Momodica charantia* (Cucurbitaceae)

Penar Bhora

Cultivation in 'Penar Bhora' is found in Brahmanbaria and Habiganj district. 'Penar Bhora' is a small floating bed of water hyacinth. The 'Penar Bhora' looks like a pile but floating like a Baira. In the wetlands of Brahmanbaria and Habiganj districts the flood water remains for a long time and the flooding frequency is more compared with the other part of the country; and there is wave action. The size of a 'Penar bhora' varies from 0.5 to 1.5m diameters. It is a simple stockpile of water hyacinths. The scale of cultivation is not as wide as Baira or Bhasan Chas. This is basically an extension of the kitchen garden. By putting some soil on 'Penar Bhora', the farmers place the seeds. It was recorded that only the Bottle gourd and Pumpkin are cultivated in 'Penar Bhora'. It is very easy to move. In the late monsoon the farmers take 'Bhora' where they decide to set the climbers.

Mulching

Mulching is a common practice in the Satkhira region. Dried water hyacinth is used like carpet in the vegetable

garden and field mostly. Mulching for a single plant was also recorded for fruit plants. According to the community the mulching is useful to keep the soil moisture and also helps reduce the salinity. Powder of salt was found on the top of the mulched water hyacinth layer in Munshiganj, Satkhira. This is because of the evaporation of saline water from the soil.

Mulching was also recorded from Haor basin and Charland where the main objective is keeping the soil moist. In the Haor basin the water hyacinth mulching is a common use of cultivating Groundnut and Potato. Mulching of water hyacinth in Bikrampur, Munshiganj helps for the good color of potato.

Apart from the Mulching in the crop field it was found popular in the kitchen garden and homestead framing. Very commonly the pith Mulching of water hyacinth is used to grow the Water Gourd.

Promotion by Development Actions

Adaptation to climate change is already an urgent priority for Bangladesh. The practice of 'Baira', 'Bhasan Chas' and 'Bhora' has potential use when the flood became more frequent and devastating. There were some interventions for the extension of cultivation in Baira. The Reduce Vulnerability of Climate Change (RVCC) project, the first climate action project in Bangladesh has facilitated the susceptible communities to adapt to the adverse effects of climate change by adopting Baira as a new farming option. The Sustainable Environment Management Program (SEMP) has worked for the extension of 'Baira' practice through the local community. NGOs like IUCN, Center for Natural Resource Studies, Bangladesh Center for Advanced Studies and VERD have practiced it in Haor Basin, where the wave action is a problem.

Ecosystem-Specific Use for Sustainability

The Water Hyacinth availability is not unique everywhere. Uncontrolled growth of water hyacinth is a problem for the water ways. The plan is very fast growing if there is an enabling environment. Use of water hyacinth in agriculture will not only make the farming climate adaptive but also helps the water navigation by controlling the overgrowth of the floating aquatic weed. A very prominent challenge is the attempt towards the unique use of the species, most development projects being practicing the floating bed, baira, irrespective of the ecosystem challenges. That is one of the main regions of failure stories on climate change adaptation. Many organizations including the government also tried to have baira of Gopalganj type in the Tanguar haor and other Haor areas. The Haor has wave action which is locally known as "Afal". The Gopalganj type Baira is not an adaptation option for agricultural farming in the Haor basin

Discussion

The National Adaptation Plan of Bangladesh 2023-2050 has goals to develop climate-resilient agriculture. Encouraging interactions, transfers of innovative technology and knowledge, learning from indigenous know-how, and the development of skills and awareness, is a priority action in NAP (GoB, 2022). CARE Bangladesh has initiated the project RVCC in Jashore, Narail, Bagerhat, Khulna and Stakhira to extend the Baira cultivation (CARE Bangladesh, 2004). Hossain (2014) reported 5 crops cultivated in Tungipara, Gopalganj, the current study found more species. According to Gupta, *et al.* (2021) short-rooted vegetables and leafy vegetables are best-suited to floating gardens. Spinach, amaranth, coriander, brinjal, tomato, beans, ladyfinger, chilly, bitter gourd, chili, mint, etc. are a few of the plants cultivated in Majili, Assam, India. Not only the indigenous practice by the farmers, climate change adaptation projects by different NGOs also have influence of species diversity increase in floating cultivation. Haq *et al.* (2002) reported that in Baira farming pests attack and disease infestation is comparatively low. The use of such platforms made up of plant material to grow plants dated back to a few thousand years. It is also found in some parts of India (in Dal Lake, Kashmir and in some floodplains in Assam) and Myanmar (in Inle lake in southern part of the country and locally called Yechan) (IUCN Bangladesh 2005). Irfanullah *et al.* (2022) noted floating gardens as an adaptation efficient to cope with water logging. The impacts of waterlogging extend to the post-disaster period and make communities vulnerable to vicious cycles of losses, lack of capacity and poverty (Islam, 2020). Bayu *et al.* (2022) found that due to climate change the growth of water hyacinth will increase. The seasonal increase in rainfall caused by climate change has significant direct effects on the composition and phenology of invasive plant communities (Guo *et al.*, 2020). The increase in rainfall and temperature favors the existence of water hyacinth because water hyacinth can more easily adapt to the fluctuation of temperature and rainfall than other species. Fluctuation of temperature and rainfall allow dominance of water hyacinth on the surface of the lake affecting the phenology of the plant community in the lake. This could be due to heavy rainfall and subsequent runoff removing nutrients from various land use systems. The availability of nutrients resulting from high rainfall facilitates the growth and invasion of water hyacinths. Future availability of the plant and its use diversification will help the climate actions.

Harun, *et al.* (2021) recommended Empowering locals with opportunities and enticing them with potential economic gains can be a nudge towards a pro-environment behavioral change in managing Water hyacinth. This would aid in upgrading local livelihoods and could foster resilience within the community in tackling both environmental problems and economic setbacks through the management of Water hyacinth invasions.

CONCLUSION

Water hyacinth has been a problem for over a century globally at least since the 1980s. It negatively affects ecosystem services and the ecological conditions of aquatic environments. Diversified use of water hyacinth

in agricultural adaptation practices can help control the population of the species. The indigenous and local technologies are not well documented. During the study designing 22 papers have been found published in different journals that noted the use of water hyacinths in agriculture in Bangladesh. Most of the articles were on 'Baira', a few described the Mulching, but none noted the 'Bhasan Chas' and 'Bhora'. The Community Based Adaptation and Locally Led Adaptation have huge potential using the water hyacinth based agricultural technologies. Considering the broader ecological classification of the country the findings can state that the Baira is a good technology for the Beel Basin whereas the 'Bhora' is for the Haor basin of the country. Mulching has a scope of salinity control. Since mulching helps keeping soil moisture; It could be a good adaptation option for the Barind region also. It was found from the experience that the scope of cultivation in 'Baira' in Haor basin has no potential. Though number of policy papers suggested the floating bed in Haor but the study findings suggest that the recommendations of adaptation options should not be that common since the country has a wide diversity in agro-ecosystem. The practicality should be considered in promotion of adaptation technology. An adaptation option inappropriate with ecosystem has high risk of tearing to a maladaptation. In Haor instead of promoting Baira the practice of 'Bhora' can be facilitated. Because of climate change water logging especially the slow and late runout of water is a problem for part of the country. The 'Bhasan Chas' may have a potential scope for those areas. It was found from the consultation that no initiative has been taken for the extension of 'Bhasan Chas'. But the community feels that it is possible to extend it widely. Water hyacinth is available everywhere and is a problem for navigation in some areas. Promotion of local knowledge and technologies need proper documentation and adoption while introducing a new ecosystem. The adoption needs to address local hazards and climate change vulnerabilities, cultivation practice and pattern, availability of natural resources, etc. Climate change adaptation technologies must be economically affordable by the community. The study found that making a 'Baira' required huge amount of water hyacinths and also labour intensive. To promote water hyacinth-based adaptation technologies the development and adaptation interventions needs to explore the availability of water hyacinths, the local land use pattern, ecology and hazards of the locality and the cultural practices. Considering all those aspects, water hyacinth base cultivation technologies were found to be the best option towards climate smart agriculture. For that knowledge management is also an essential aspect, that must include ecological interaction and form of knowledge transformation.

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