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CONTENTS

General Instruction for Preparation of Manuscript

Articles dealing with the past activities, present status and future guidelines in one or more disciplines of agriculture will get priority for publication in this journal. Original research work, both fundamental and applied will also receive priority. Articles published in this journal will not necessarily be reports on original research results only. The articles, in addition to being on research results, should preferably be on policy, management, advancement and frontier issues of research, extension and economic aspects on different disciplines/ subjects related to agriculture. The disciplines/ subjects would encompass all sub-sectors of broad-sense agriculture i.e, crops, fisheries, livestock, forestry, environment, economics etc.

The topics may also entail current and future scenarios for improvement of sustainability of the fragile eco-system, food security, natural resource management, input distribution & management, nutrition, agribusiness, climatic risk management, human resource development and economic implications of rapid globalization obtaining since the recent past. The retrospects and prospects of agricultural improvement vis-à-vis the constraints hindering progress of agricultural development etc are burning topics needing elaborate analysis and synthesis for the policy markers , teachers, researches, extensonists, service providers, marketing agents, NGOs and private sector entrepreneurs.

The authors are to note the following instructions.

1. Typing the manuscript: Manuscript should be typed in double spacing on A4 size papers leaving at least 2.5 cm in all sides. The text and tables may be typed in 10 points and 4 or 6 point type, respectively on one side of the page only. The full-length articles ordinarily may not exceed 10 typed pages including Tables, Figurers and References.

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4. **Abstract: The abstract should be completely self-explanatory in a single paragraph summarizing the objective, method(s), contents and conclusion of the topic. It should be typed in italic font.**

5. Original research based full-length article may have the following main headings: Introduction, Materials and Methods, Results and Discussion followed by a Conclusion. If possible, Review- based articles should be described under necessary headings and sub-headings with comments on each and every important item of discussion.

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8) Literature citation: In the text citation should be made consistently following the " Name and Year Systems" as Shaikh (1998) or (Shaikh,1998) in case of single author, Alam and Miah (1997)in case of two authors or Rahman etal., (1996) in case of three or more authors.

List literature citations, references or bibliography at the end of the paper in alphabetical order. Examples:

1. Ahmed S.S. 1997. Cytogenetics of the jute, Bangladesh. Jute Fibre Res.10(2): 107-110.
2. Ali, M.S., S.A. Khan and A.R. Chowduary, 1998. Production of rice in the changing climatic condition of Bangladesh. Bangladesh Agriculture: 1(1): 9-13.
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5. Rahman, S.1987. Water stress in potato. In: Annual Report, Bangladesh Agric, Res. Institute, Gazipur, Pp. 170-190.

Editor

Two hard copies and a soft copy should be submitted.

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Managing Organizational Change: Lessons from Uganda Experience

M.M. Rahman[1]

Abstract

Organizational change is necessary at certain interval, and at times, becomes essential to adjust and orient itself to effectively respond to new social requirements and face the challenge of emerging issues. However, managing organizational change is a difficult and strenuous process, particularly in the public sector organization, where power structure, resource control, diverse group interest and cross current are deep rooted. This paper discusses the lessons learnt from a practical exercise in managing organizational change in a public sector institution. It describes the process of managing organizational change, the type of problems faced and the interventions required to find the solution. The paper also highlights the outcome of the exercise. Experience clearly shows that strong Government commitment and support is essential to bring major change in the public sector organization.

1.0 Introduction

1.1 Organizational change is a periodic feature in the private sector enterprises. They change to adapt themselves to new environment and to make the organization responsive to new social requirements. This is a normal culture of the private sector organization. They need to do it to remain competitive in the market. It is, therefore, less difficult to induce changes in these organizations, excepting those dealing with cross-cultural problems. Organizational change does not occur so easily in the public sector institutions. In the public sector organizations, small changes do take place; but it is difficult to introduce major changes.

1.2 The Uganda experience is a confirmation of author's past experience that inducing organizational change in a public sector institution in the developing countries is generally very difficult. Small changes can be induced internally. But any major change requires high level Government support; sometimes pressure, particularly if changes are to be induced in an institution with old tradition and culture. It is a sensitive and difficult process. It requires a great deal of efforts in managing the internal and external forces having different perception of change linked to traditional culture and vested interest. This paper discusses the author's Uganda experience in managing organizational change, the lessons learnt and the outcome achieved.

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2.0 The Need and Perception of Change

2.1 The critical aspect of managing organizational change is the need of a clear understanding of the necessity and perception of change. It is very important to ascertain:

- Why the change is needed?
- How urgent is the need for change?
- Change for what and for whom?
- How strong is the support for change and at what levels?
- Why the change is not taking place, if it is so necessary?

2.2 The reviews carried out in Uganda by IDRC (1982), MoA (1984) and SPAAR (1987) revealed that Uganda's economy is primarily based on agriculture, but the very poor agricultural services were unable to support economic growth. Similar reviews were done in the livestock sub-sector by Winrock International (1984) and MAIF (1989); fisheries sub-sector by MAIF (1989), Kidhongania (1990) and Orach Meza (1990); and forestry sub-sector by Plumptre (1984 & 1985), UNDP/WB (1986) and Kaomi (1989), showing very poor service conditions in these areas. ISNAR/USAID reviews of agricultural research in 1987 and 1988 vividly described the weaknesses of the agricultural research services. Hartmans (1989) and Rao (1990) also reported very poor conditions of agricultural research in the crop sub-sector. These reviews identified the need for institutional change to rejuvenate and reactivate agricultural research for supporting the economic development program undertaken by the Government. They also identified the following specific reasons for the desired changes:

- The research system, established during the colonial era, was designed to address the problems of industrial commodities of interest to the colonial government and not of the food commodities for food security of the population.
- The research network, spread over several Government Ministries, was severely damaged during the protracted civil war.
- The system failed to respond to the emerging development needs of the newly independent country.
- Research was not making any contribution to the "Economic Recovery Program" undertaken by the Government.
- Farmers were not getting any benefit from research.
- Service conditions sharply deteriorated after independence.
- Staff salary remained very poor.
- Funding support for research was all time low.

- There was no incentive for devoting time to research.
- Career development opportunities were totally absent.
- Staff moral was very low.
- Good researchers deserted the system in quest of higher income to support their family; those remained in the system were engaged in activities not even remotely related to research.
- The Government found it difficult to feed the people, develop the agro-industries, and boost the national economy without improving agricultural productivity.

2.3 This desperate situation created a tremendous internal urge and external demand for a major overhaul of the existing research system. Organizational change was urgently needed to reactivate the national research system to support agricultural growth. The demand for change was widespread at all levels. Yet, nothing much happened until the initiative and support came from the highest level of the Government with commitment of donors for financial support. Sporadic efforts were made to improve the situation, but it did not work, because these efforts could not address the fundamental issues without direct involvement and intervention of the Government at a higher level.

3.0 Perception of Change

3.1 If the need is urgent, all parties may lend support to it; but it does not necessarily mean that the purpose and perception of change of all parties are the same. The Uganda experience clearly shows that the perception of change can vary widely. The internal environmental scanning showed that although the support for change was widespread at all levels; the perception of change was different. The perception of the Ministry was to improve and expand the research facilities within their own territories without major structural and administrative change. The regional forces wanted to have equal research coverage with a number of research institutes/stations. The Institute Leaders wanted more power and authority along with higher remuneration with improved facilities. The Division/Unit Heads wanted adequate facilities, funds, staff, and flexibility for use of resources, and, of course, higher remuneration package. The scientists and the technicians demanded improved service conditions and career development opportunities. The Extension Department was supportive of improving the research facilities, but opposed to improving the service conditions that would provide special benefits to researchers. They wanted research to remain as one of the Divisions under their administrative control. Evidently, all parties wanted to protect their interests and territories. It was also revealed that the support from within the research system was not as strong for improving the organization, governance structure and management system as it was for improving the research facilities, service conditions and salary package. When the question of change such as downsizing the research network, improving research planning and management system, performance assessment and accountability was raised, internal resistance began to surface. The support for such changes was not loud.

3.2 Government's perception of change, on the other hand, was different. They wanted a major overhaul that would integrate the dispersed research network into one single national organization. They wanted an institution that would be able to plan, coordinate and implement priority research programs in the various sub-sectors of agriculture in a coherent manner. Here, again, some of the top research leaders found an opportunity to expand the kingdom and create a new power base. Therefore, the understanding of the diverse needs and perceptions of change is extremely important for planning, designing and managing the organizational change process.

4.0 Critical Requirements for Managing Change

4.1 One of the critical requirements for managing organizational change is the presence of an enabling environment. If the environment for change does not exist, it needs to be created and maintained throughout the process of change. Other critical requirements include:

(a) A widely respected visionary leader to lead the change process;

(b) Minimum internal capacity (skills, experience and facilities) to manage the process;

(c) External technical support with right experience to complement and blend the traditional system with modern concept;

(d) Necessary financial and physical resources; and

(e) Supportive political and economic environment.

4.2 Efforts of managing organizational change are likely to run into serious problems, if these requirements are not satisfied. In Uganda, the in-house capacity for managing organizational change was very low; experience in institutional reform was totally lacking; internal environment, at times, was deceitful; and the available resources were limited. The exception was that the top leader was committed and ready to struggle all the way to lead the process to a successful end. Government's commitment and donors' support were the main pillars. Despite the internal squabble and high tension between the Ministries, regional groups, research and extension camps, and power structures within the system, the Government was firm in its commitment to implement the policy of integration and consolidation of the research network. The donors came strongly in support of this policy. This development was seen both as a pressure and an opportunity.

5.0 Designing the Change Process

5.1 Planning and designing the organizational change process is an important step. This is essentially determined by the nature and scale of changes that are desired and expected to be attained. Organizational change in Uganda involved changes in research policy, organization and management systems. This meant a major overhaul. The whole range of issues in these areas needed review. There are, of course, different ways of planning and designing the change process.

The Uganda exercise was designed to adopt the two familiar processes in achieving the desired organizational change:

1. Strategic planning
2. Capacity building

5.2 Experience shows that the job is better done through a strategic planning process. This is the most important process to guide the major organizational change. Strategic planning is a consensus building process in which the concerned parties can be brought together for debates and discussions on what to change and how to change. It is a process that provides the opportunity for building strategic alliance with partners, stakeholders and opponents. It provides the best forum to raise and discuss the wide range of views and ideas, and reach agreements on issues that are critical for making decisions on strategic change. In this process, the most important part is the synthesis of collective views and ideas for reaching agreements. Management of this part is more difficult and at times frustrating; but this is where lies the challenge and the real opportunity for success. When the perception of change varies widely, cautious treatment of the intent and the perceived idea of change of various groups become extremely important in reaching agreements. The bitter task in the process is the management of internal forces and cross currents.

5.3 In the capacity building process, measures are essentially taken to create the means, and provide the necessary management instruments for implementing the change. This process is important not only for creating the means but also for building confidence and a healthy institutional environment. The success of implementing the change, however, depends on two important factors: (i) Government's commitment to provide the needed resources on time; and (ii) Research Managers' commitment to the task.

5.4 The lesson, drawn from this experience, is that at certain points, some amount of pressure is needed to reach agreements on specific fundamental issues of national interest. It is possible to apply such pressure during strategic planning as the Government is, in one way or other, involved in the decision making process. It is difficult to use pressure during the implementation phase. Implementation is an internal process, and it remains relatively free from external pressure. It is mainly related to management of human resources and cultural influences.

6.0 Managing the Change Process

6.1 This involves management of the process of arriving at decisions on strategic changes (strategic level), followed by management of the process of implementing the changes (operational level). Managing organizational change is basically managing the people who manage the change process at both the strategic and operational levels. In this task, the important step is to plan and organize the change process in the best possible manner. In Uganda, the process was organized and managed at three levels as described below:

Levels	Management Groups
National level	Agricultural Policy Committee (APC) reporting to the Cabinet
Sector level	Task Force and Working Group reporting to APC
Organization level	Top Research Managers

6.2 APC, the Task Force and the Working Group were operating at the strategic level. They were responsible for evaluating the need for change, diagnosing what to change, and creating conditions for taking decisions on strategic change. Top Research Managers were working at the operational level. They were responsible for managing the process of implementing the agreed changes.

7.0 Managing Change at Strategic Level

Policy Committee

7.1 The Policy Committee was primarily a supervisory body to follow up the progress and resolve issues that needed Government interventions. The Committee was constituted by inducting the Permanent Secretaries (PS) of all sub-sectors of agriculture and related sectors, including the University Faculty of Agriculture. It was headed by the Permanent Secretary of the Ministry of Finance and Economic Planning. The advantage of having a high level committee as this is that the PS has the decision-making authority for his/her sector/sub-sector, and any decision taken at this level is considered as Government decision. The lead role of APC was to ensure consistency between policies, sectoral development goals and objectives, research program priorities, and resource allocation to research.

7.2 A strong secretariat with adequate facilities was established to serve the Policy Committee. The responsibility of the secretariat was to organize and facilitate meeting of the Committee regularly to discuss the findings of the Task Force and Working Group, and to provide necessary policy guidance. Such a Committee is essential not only to create pressure (internal urgency) on the Task Force and the Working Group but also to moderate the views of various pressure groups and donors, and deal with issues that need to be resolved at national level.

Task Force

7.3 The Task Force was set up to conduct a system-wide diagnostic review to assess the strengths and weaknesses of the system. Eminent scientists were in the Task Force with an ISNAR specialist. A specific timeframe with detailed terms of reference were given to the Task Force for completing the review. The findings and recommendations of the Task Force were reviewed by the Policy Committee and the donors. These recommendations formed the terms of reference of the Working Group.

7.4 Diagnostic review is a very important step. Half the work is accomplished, if the review is done well. Diagnostic review often looks at the problems and the requirements of the research system and not at the requirements of the beneficiaries. Such a review can be misleading. It is, therefore, very important to involve the stakeholders and the direct beneficiaries of research in the review process. Sometimes, the review looks only at the quantitative aspects and not at the qualitative aspect; and sometimes, it takes a general view of the system and not of the component parts of it. This is likely to lead to wrong conclusions. The Uganda review had some of these deficiencies. The information on certain areas was not adequate; for example, there was no information on scientific personnel and their skill profile (Zuidema 1990), information management (Woodward 1990), and research and resource management systems (Serafini 1990). The good part of the diagnostic report was that the review did not give solutions to the problems, but it recommended for undertaking a strategic planning exercise as a step to find solutions toward building an effective and efficient research system.

Working Group

7.5 The task of this group was to prepare a strategic plan, including appropriate reorganization of the research system. The working group was formed with members from research and extension personnel and the University Faculties with an ISNAR Specialist (the author). All sub-sectors of agriculture (crops, livestock, fisheries and forestry) were fairly represented. A secretariat was set up to facilitate the work of the group. The task of this group was more difficult. They were the ones who were responsible for building consensus on strategic changes.

7.6 The working group organized the strategic planning process by identifying the areas to be addressed (components of strategic plan); and assessing the information and other important requirements.

Components of Strategic Plan

7.7 The Group identified the following areas as important components of the strategic plan:

- Research policy
- Research strategy
- Research priorities and programs
- Rationalization of research stations
- Organizational structure
- Research system linkages
- Improving research facilities
- Research support services (research stations and information management)
- Rationalization and management of human and physical resources
- Organization and management of research programs
- Financial plan and management

Information Requirements

7.8 In the Task Force report, information on many important areas were either missing or insufficient. One of the major tasks of the working group was to conduct in-depth review of some of the components that the Task Force could not accomplish. These components included:

- Research management
- Human resource management
- Financial management and program budgeting
- Physical resource management
- Agricultural knowledge and information management
- Research station rehabilitation and management

7.9 Information and data on the current status, and the strengths and weaknesses of the system in these areas were missing. It was also necessary to collect information on scientific personnel, research and resource management systems, and rehabilitation requirements of the major research stations as inputs to strategic planning.

Other Requirements

7.10 Other important requirements identified by the working group were:

- Launching motivational campaign within the research system, including the University
- Developing strategy for building coalition with partners and stakeholders

- Forming sub-groups to review specific areas of concern
- Appointing consultants and resource persons for specific studies as needed

Motivation Campaign

7.11 Due to decade-long civil war, the agricultural researchers lost links with new advancements in agriculture that took place in the Green Revolution era. They had very little understanding of how the other developing countries adjusted and continued to adjust their research systems to meet the new development challenges under the changed environmental context. They were not subjected or used to systematic thinking and orientation for future requirements. The working group launched the motivational campaign to create awareness and mobilize staff opinion in support of changes for system integration and sustained improvement of the research environment. Such motivational campaign is sometimes necessary not only for securing support but also for ensuring effective participation and cooperation of the staff and others in managing the overall change process. Staff participation is important, because they are the ones who will implement the change.

Building Coalition

7.12 The most critical intervention was building coalition with the partners, the stakeholders and the negative forces, in particular. The working group found it very difficult to mange the internal and sub-sectoral forces, especially with regard to the following issues:

- Integration of crop, livestock, fisheries and forestry research under one national research organization
- Specification of research institutes, regional stations and sub-stations by sub-sectors of agriculture
- Downsizing the research establishments by eliminating some of the existing stations
- Manpower rationalization by reducing redundant staff, where necessary
- Placing the new national research organization under the Ministry of Agriculture
- Autonomy of the organization
- A Governing Board to be headed by an eminent scientist and not by a minister or a civil servant

7.13 There was fear in some quarters of loosing the territory, the sphere of influence and above all the resources. The station Directors were afraid of loosing their dominance and independence, and being subjected to accountability for resource use and research outputs. They were also apprehensive of loosing their positions like some of the other staff. Managing this fear was crucial. The following management strategy was adopted by the working group: (i) be positive to the views of all concerned; (ii) be well informed of all issues; (iii) remain transparent and unbiased in dealing with sensitive issues; (iv) involve important stakeholders in the planning process; (v) avoid gaps in communicating with the stakeholders; (vi) motivate and convince the staff that changes are for the benefit of the majority and for the survival of the system; (vii) develop alternatives for assuring the losers; (viii) establish good rapport with the power base of the concerned ministries; and (ix) communicate effectively with the Policy Committee.

7.14 This strategy greatly helped in building confidence and creating conditions for reaching agreements on strategic change in most of the critical issues. In most cases, pressure was avoided. Experience shows that pressure may work in taking decisions; but it seldom helps in implementing the decision. Participation of stakeholders in the decision-making process is more important than any other strategy in managing and inducing organizational change.

7.15 The success of managing the change process depends, to a great extent, on active participation of the stakeholders in developing the vision, and defining the goals and objectives of the organization. It is important for them to know the future direction of the organization with which the benefits they expect are associated. It is necessary to ensure participation, especially of the change implementers. They need to know how their own position is potentially affected; how their individual role fits within the objectives of the organization; and how they can contribute to achieving the desired goals and objectives. If the key implementers are not involved in sharing the vision, goals and objectives, implementation of change becomes very difficult. This is not to say that their involvement always guarantees smooth implementation. There will always be some unfavorable elements with negative attitude that can create problems, even if they are involved. This is what was also experienced in Uganda. Older generation was more conservative. Younger scientists were more open.

8.0 Managing Change at Operational Level

8.1 This is the most difficult part of the change process. It is at this level, the changes are implemented. The top research managers face many more questions and issues in managing the implementation process. The Uganda research network was reduced in size, and the research programs in all sub-sectors were rationalized, based on agreed priorities. Consequently the staff strength was reduced. This created fear among many staff, particularly the non-performers, of loosing their jobs and being deprived of the benefits that are associated with the change. Some were suspicious about the promised improvement in service

conditions and research facilities. The major problems faced at this level were in the following areas: (i) staff recruitment and deployment; (ii) management of surplus and redundant staff; (iii) improving the research and resource management systems; and (iv) staff performance assessment and accountability.

8.2 In managing these problems, the national research organization followed a transition process. They recognized the need for sequencing the implementation of the changes over time in the belief that gradual change will be more easily acceptable than the radical approach. The transition plan was designed to include two phases: Phase 1 (2- year) was more of a capacity building and confidence building phase. In this phase, the following tasks were accomplished that helped in building confidence:

- Promulgation of the Statute establishing the National Agricultural Research Organization (NARO)
- Constitution of Agricultural Research Board (the Governing Board)
- Appointment of Director General and senior NARO managers
- Establishment of a new Scheme of Service with better terms and conditions and much enhanced remuneration package
- Staff development plan
- Phased recruitment and deployment of staff
- Development of alternative strategy for surplus staff
- Creation of improved research facilities, including rehabilitation/ development of selected facilities
- Strengthening/establishing linkages with clients and external institutions
- Design and installation of new management systems prior to actual integration of research staff and research programs (on-going research projects were allowed to continue with direct support from internal and external sources or progressively through NARO)
- Securing funds to support the planned programs and activities

8.3 This approach boosted staff moral and created enthusiasm among them that helped achieving the desired objectives. This also greatly facilitated the work of the second phase (4-year) which included:

- Continuation of facility improvement
- Progress in staff development
- Improving research system
- Evaluation of on-going programs
- Development of detailed medium-term research programs and priorities with the inclusion of potential on-going projects

- Launching an action research and development program with extension for rapid transfer of available technologies to demonstrate the impact of reorganization

8.4 Management of surplus and redundant staff was the biggest headache. An alternative strategy was worked out in cooperation with the Ministry of Agriculture and the Public Service Commission. According to this strategy, the issue of surplus staff was resolved in the following manner:

1. Absorption of staff with aptitude in administrative work in the newly created administrative positions in NARO; some were absorbed in farm management positions.
2. Transfer of staff, suitable for extension job, to the Extension Department as Subject Matter Specialists.
3. Those who have few months to one year to retire were retained until the retirement date. Those who wanted early retirement were allowed to retire.
4. Those who have ill reputation and corruption charges against them were placed at the disposal of the Public Service Commission for retirement under the Government's forced retirement scheme.
5. Group employees (ad-hoc appointees) were retrenched under the Government's retrenchment scheme.

8.5 Some of the old staff, found unsuitable for higher position, was posted to lower position without affecting their salary. Alternatively, they were given the option to retire. However, all of them accepted the offer because of lucrative remuneration package. There was murmuring for sometime without support from any quarter, and with time the resentment died its natural death. It is not easy to find good solution for all in a system with limited opportunity. Sometimes, unfriendly measures become a necessity.

8.6 The toughest of all tasks was to manage the process of introducing the concept of modern management system. Uganda's research system was quite old. Its hierarchical civil service management system was deep rooted. It was linked to power structure. The managers were used to this management culture. It was, therefore, extremely difficult and time consuming to establish improved organizational management systems that ensure transparency and accountability. The major conflict was between the hierarchical and collegial style of management. Some top managers were initially stubborn to accept the new system; others were open-minded. This is, of course, the question of attitude and management perception. Many of these problems are related to both organizational and national culture, particularly with regard to resource management. For example, the research institutes followed the Government budgeting and accounting system which is absolutely not suitable for research organization. Same is the case with human resource management system which followed the Public Service rules and regulations. Obviously, this is the influence of the national culture. However, it took longer than expected to establish improved management system. It is still not entirely error-free due to lack of internal managerial capacity.

8.7 Research culture is organization-specific. It is influenced by organization's own environment such as power structure, leadership style, institutional setting, decision-making process, and functional policies and management systems. Research culture in Uganda NARS was corrupted by old organizational culture. Initially, the scientists were not ready to accept changes in research planning, priority setting, program budgeting, monitoring and evaluation, staff performance appraisal, accountability for research output, and financial reporting. The main reason was that they were not familiar and exposed to these new systems. They were also suspicious about the purpose; and some showed the tendency to avoid close scrutiny of what they do. NARO management introduces these systems in a gradual fashion. They were using two main strategies for this purpose – one, involving scientists in system development; and two, regulating funding support to programs not following the new system. Both strategies worked very well. The progress was smooth with the involvement of scientists in system development. They were able to see for themselves the usefulness of the new systems, and understand that these are management instruments to improve research performance and not to use against them. The best example was in the case of priority setting, research program formulation and budgeting. It took two years to convince them to put the systems in place. Later on, some of the initiatives started coming from the scientists themselves.

9.0 Outcome of the Initiative

9.1 The change management process was difficult and the exercise was strenuous, but the initiative set the best example of institutional change in a public sector organization. It has given new life to a dead organization through the changes that include:

1. Downsizing the proliferated and highly scattered research establishments and rationalizing the research and support staff.
2. Integrating crops, livestock, fisheries and forestry research under the Statute of one single institution, called the National Agricultural Research Organization (NARO) with three crops, one livestock, one fishery and one forestry Research Institutes with limited number of regional stations as its research arms.
3. NARO is governed by a relatively small independent Research Board, headed by a nationally recognized scientist with members drawn from each sub-sector of agriculture and farmer representative.

4. NARO retains the authority to define research policies, research priorities, resource allocation, human resource management and information management. The headquarters of NARO acts as the Secretariat of the Research Board. NARO has one service rule and salary structure for the entire system.
5. NARO has a budgetary vote to receive research funds directly from the Ministry of Finance and Economic Planning. It is directly accountable to the Government.
6. NARO has established a collegial style of management by setting up a Program Management Committee consisting of Institute Directors. The Committee is chaired by the Director General of NARO.
7. NARO has established a highly lucrative remuneration package with a strong staff performance assessment system for rewarding the staff for high quality research works.
8. The NARO staff salary in Uganda shilling is pegged to dollar to protect it from highly fluctuating Uganda currency.

10.0 Conclusion

10.1 Uganda experience shows that to bring about organizational change in the public sector institution, strong Government commitment and support is essential. Management of change requires special skills and committed leadership. The successful management of the process of implementing the changes requires four pre-conditions: (i) a strong Management Board; (ii) committed research leaders; (iii) internal scientific and managerial capacity; and (iv) minimum facilities to carry out the job.

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Regeneration Performance of Food Tree Species for Hoolock Gibbon in Lawachara National Park, Bangladesh

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Abstract

The aim of this study was to investigate indirect impacts of climate change on Hoolock Gibbon (Hoolock hoolock) by studying regeneration status of food trees species in Lawachara National Park (LNP). To complete this study quadrate plot survey method were applied. Plots were taken randomly and measured quantitative parameters (Density, Relative density, Frequency, Relative frequency and Abundance) of plant communities. This research identified that density of food tree species was highest in seedling stage but in pole stage performance was not satisfactory due to climatic and anthropogenic causes. Non-food producing tree species showed excellent performance both sapling and pole stage with regard to density, relative density, frequency and relative frequency. The replacement by non-food trees occurred due-to change in micro climatic factors such as rainfall, temperature, humidity, aspect, sunshine and soil. Among the food producing trees, Artocarpus chapalasha showed good result in regeneration in stipulations of seedlings, saplings and poles stages. But Artocarpus chapalasha was seasonal fruit trees thus food deficiency was common issue for Hoolock Gibbon in LNP. As a result Hoolock Gibbon population has been decreasing in course of time. This study can be recommended that decreasing trend of food bearing trees and number of Hoolock Gibbon can be partially or totally stopped if proper management steps are taken.

Keywords: *Regeneration status, Hoolock Gibbon, Climate change, Quantitative parameters, Food tree species, Lawachara National Park.*

Introduction

Hoolock Gibbons (*Hoolock hoolock*) are socially monogamous small apes and plays imperative functions in ecology in the tropical forest (Chivers, 2001). They exist forming a group (2 to 4 individuals) in the forest (Chowdhury, 1996). Each group has their own territory of about 30 hectares, which they defend from other gibbons by loud songs (IPAC, 2012). Geographically Hoolock Gibbons are scattered in north-eastern states in India and total population is more than 2,600 individuals (Molur et. al., 2005). In Bangladesh, Hoolock Gibbon populations were estimated to be around 3,000 individuals in the mid 1980 (Gittins and Akonda, 1982). This number had later crashed about 200 individuals and scattered

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in 22 small populations (IPAC, 2012). At this time, the species are globally endangered (IUCN, 2004) and in Bangladesh, they are classified as critically endangered (IUCN, 2000). The declining trend continued in many areas of Bangladesh, with some areas having lost all of its Hoolock Gibbons (Feeroz, 2001, Das et. al., 2003, Islam et. al., 2004). Due to high plant diversity, Lawachara National Park (LNP) is the last stronghold for the Hoolock Gibbon in Bangladesh (IPAC, 2012). There are 60 individuals with 16 families of Hoolock Gibbon exist in LNP (IPAC, 2012). Fewer numbers of Gibbons are present in Kaptai, Satchari National Park and Rema-kalenga Wildlife Sanctuary with unproductive situation (IPAC, 2012 and Islam et. al., 2004). They have been under considerable threat primarily due to poor regeneration status of food trees and habitat destruction all over their range (Gittins and Akonda, 1982, Gittins, 1984, Gittins and Tilson, 1984, Chivers, 2001, Islam et. al., 2004).

Hoolock Gibbons are mainly fruit borer in the forests of Southeast Asia, supplementing their diet with flowers, juvenile leaves and infrequently insects. A variety of plant such as *Artocarpus chapalasha, Bixa orellana, Dipterocarpus spp., Syzygium spp., Mangifera sylvatica, Protium serratum, Entada spp., Ficus spp.* and *Lagersrtoemia speciosa* are important for food sources and habitation of Hoolock Gibbon (FD, 2010). The relative frequency and relative cover of these species was highest in LNP (Ahsan, 1994, Ahsan, 2001). At present these native species are losing at alarming rate due to rapid degradation of forests in LNP (Rahman et. al., 2000, Hossain, 2001). Deforestation causes a decrease in catchments area water holding capacity, increased soil erosion, and the loss of habitats and biodiversity. Regeneration is essential for conservation and maintenance of biodiversity (Hossian, 1989). But regeneration status of food species in LNP greatly is influenced by microclimatic factors such as rainfall, temperature, humidity, aspect, sunshine and soil (Philip, 2006). For this rationale, a study was conducted to explore indirect impacts of climate change on Hoolock Gibbon by studying regeneration performance of food trees species in LNP.

Methodology

Study area

The study was conducted in the Lawachara National park (LNP), Bangladesh (Fig. 1). It is a part of the West Bhanugach Reserved Forest and located in Kamalgonj Upazila in the district of Moulavibazar. LNP lies in between 24°30′-24°32′N and 91°37′-91°47′E which was established on 07 July in 1996 and current notified area of the park covers of 1250 hectares. Biologically LNP so much rich due to plant and animal diversity (Plant 167 *spp*, Amphibians 4 *spp*, Reptiles 6 *spp*, Birds 246 *spp*, Mammals 20 *spp* and Insects 17 *spp*.) (FD, 2012).

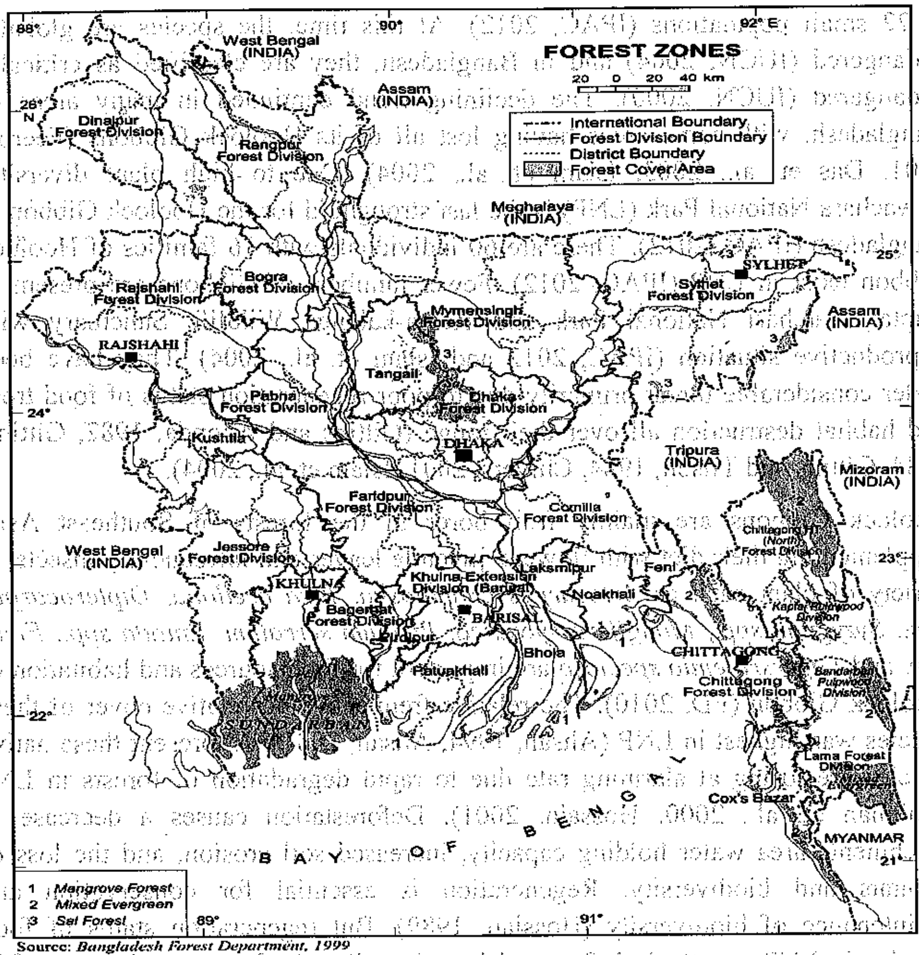

Fig. 1: Map of Lawachara National Park (LNP) (Source: Bangladesh Forest Department, 1999)

Methods

The study was conducted through quadrate plot survey method (Shukla and Chandel, 2000). Plots were taken randomly and the size of regeneration survey plot was 2m×2m. From the same plot; collar diameter, total number of regeneration (seedling, sapling and pole) for each tree species were recorded. For the easiness of the analyzed, regeneration were classified into three categories on the basis of diameter. Having the diameter 0-2cm was recorded as seedling, 2-4cm recorded as sapling and 4-6cm recorded as pole. The data of seedling, sapling and pole were applied to predict the future tree composition of LNP by modifying standard method (Gyan and Raghubanshi, 2006). The study period of this research was from February to May, 2012.

The following quantitative parameters were used to measurement the structure of plant communities.

Density (D) = TIS/TSP .... (1)

Where, TIS = total number of individuals of a species in all sample plots, TSP= total number of sample plots.

Relative density (RD) = TIS/TIAS×100 .... (2)

Where, TIS = total number of individuals of a species in all sample plots, TIAS = total number of individuals of all species.

Frequency (F) = TQS/TQ×100 .... (3)

Where, TQS = total number of quadrates in which the species occur, TQ = total number of quadrates.

Relative frequency (RF) = FS/TFS .... (4)

Where, FS = frequency of the species in a particular stand, TFS = total frequencies for all species in a particular stand.

Abundance of a species (AB) = TIS/ TQS .... (5)

Where, TIS = total number of individuals of a species in all sample plots, TQS = total number of quadrates in which the species occur.

Results and Discussion

Regeneration status and quantitative parameters of tree species

Natural and artificial regeneration were followed in Lawachara National Park (LNP) to enhance forest. Natural regeneration was maintained in the core area by creating buffer zone and artificial regeneration was done in the degraded areas by planting exotic and native species. During the study, data were collected from natural and artificial regeneration stand (Table 1).

Table 1: Regeneration status and plant quantitative parameters in LNP

Name of the species	*Total no. of species*	*No. of plot species found*	*Density*	*Relative density*	*Frequency*	*Relative frequency*	*Abundance*
*Syzygium fruticosum**	51	34	0.46	4.76	30.91	5.71	1.50
Cinnamomum tamala	41	21	0.37	3.82	19.09	3.53	1.95
Eugenia operculata	8.0	7.0	0.07	0.75	6.36	1.18	1.14
*Syzygium spp**	15	11	0.14	1.40	10.00	1.85	1.36
*Syzygium cumini**	6.0	2.0	0.05	0.56	1.82	0.34	3.00
Swietenia mahagoni	8.0	8.0	0.07	0.75	7.27	1.34	1.00
*Grewia microcos**	60	36	0.55	5.60	32.73	6.05	1.67
Aphanamixis polystachya	26	14	0.23	2.33	12.73	2.35	1.79
*Mangifera indica**	9.0	7.0	0.08	0.84	6.36	1.18	1.29
*Tamarindus indica**	7.0	4.0	0.06	0.65	3.64	0.67	1.75
*Ficus racemosa**	24	13	0.22	2.24	11.82	2.19	1.85

Garcinia cowa	14	7.0	0.13	1.31	6.36	1.18	2.00
Dillinia pentagyna	4.0	1.0	0.04	0.37	0.91	0.17	4.00
Chickrasia tabularis	18	14	0.16	1.68	12.73	2.35	1.29
*Syzygium grandis**	12	7.0	0.11	1.12	6.36	1.18	1.71
*Artocarpus chaplasha**	156	58	1.42	14.55	52.73	9.75	2.69
*Artocarpus lacucha**	39	23	0.35	3.64	20.91	3.87	1.70
*Terminalia belerica**	2.0	2.0	0.02	0.19	1.82	0.34	1.00
Crataeya nervosa	7.0	5.0	0.06	0.65	4.55	0.84	1.40
Bauhinia acuminata	30	22	0.27	2.80	20.00	3.70	1.36
Dysoxylum binectariferum	65	37	0.59	6.06	33.64	6.22	1.77
Itex godojum	11	7.0	0.10	1.03	6.36	1.18	1.57
Citrus spp	8.0	5.0	0.07	0.75	4.55	0.84	1.60
Aquilaria agallocha	23	15	0.21	2.15	13.64	2.52	1.53
Erythsina variegata	79	37	0.72	7.37	33.64	6.22	2.14
Adinal polycephala	7.0	2.0	0.06	0.65	1.82	0.34	3.50
Butea monosperma	14	5.0	0.13	1.31	4.55	0.84	2.80
Anthocephalus chinensis	15	6.0	0.14	1.40	5.45	1.01	2.50
Delonix regia	1.0	1.0	0.01	0.09	0.91	0.17	1.00
Elaeocarpus floribundas	18	10	0.16	1.68	9.09	1.68	1.80
Lagerstroemia speciosa	11	7.0	0.10	1.03	6.36	1.18	1.57
Streblus asper	4.0	4.0	0.04	0.37	3.64	0.67	1.00
Ficus semicordata	4.0	2.0	0.04	0.37	1.82	0.34	2.00
Albizia lebbeck	1.0	1.0	0.01	0.09	0.91	0.17	1.00
Cassia siamia	13	9.0	0.12	1.21	8.18	1.51	1.44
Englhardtia spicata	11	4.0	0.10	1.03	3.64	0.67	2.75
Dalbergia sissoo	4.0	3.0	0.04	0.37	2.73	0.50	1.33
Thespesia populnea	54	29	0.49	5.04	26.36	4.87	1.86
Eriobotraya japonica	10	6.0	0.09	0.93	5.45	1.01	1.67
Michelia champaca	9.0	4.0	0.08	0.84	3.64	0.67	2.25
Azadirachta indica	16	10	0.15	1.49	9.09	1.68	1.60
Tectona grandis	26	17	0.24	2.43	15.45	2.86	1.53
*Dellenia indica**	14	12	0.13	1.31	10.91	2.02	1.16
Alstonia scholaris	15	6.0	0.14	1.40	5.45	1.01	2.50
Acacia auriculiformis	9.0	7.0	0.08	0.84	6.36	1.18	1.29
Albizia procera	7.0	2.0	0.06	0.65	1.82	0.34	3.50
*Ficus roxburghii**	38	16	0.35	3.54	14.55	2.69	2.38
*Artocarpus heterophyllus**	16	13	0.15	1.49	11.82	2.19	1.23
Baccaurea ramiflora	4.0	3.0	0.04	0.37	2.73	0.50	1.33
Amora wallichii	8.0	3.0	0.07	0.75	2.73	0.50	2.67
Bixea orellana	1.0	1.0	0.01	0.09	0.91	0.17	1.00
Vitex pubescens	1.0	1.0	0.01	0.09	0.91	0.17	1.00
Careya arborea	3.0	3.0	0.03	0.28	2.73	0.50	1.00
Gmelina arborea	8.0	4.0	0.07	0.75	3.64	0.67	2.00
Derris robusta	1.0	1.0	0.01	0.09	0.91	0.17	1:00
Lophopetalum fimbriatum	4.0	3.0	0.04	0.37	2.73	0.50	1.33
Tephrasia candida	1.0	1.0	0.01	0.09	0.91	0.17	1.00
Xglia kerrii	2.0	2.0	0.02	0.19	1.82	0.34	1.00
Total	1072				540.95		
*Note: *indicate food tree species*							

Highest density was found for *Artocarpus chaplasha* (Chapalish) (1.42 seedling/plot) and moderate density was found for *Erythsina variegata* (Mander) (0.72 seedling/plot), *Dysoxylum binectariferum* (Rata) (0.59 seedling /plot), *Grewia microcos* (Pitchli) (0.55 seedling /plot) etc (Table1). *Tephrasia candida* (Bogamodula) (0.01 seedling /plot), *Vitex pubescens* (Awal) (0.01 seedling /plot), Xglia *kerrii* (Lohakat) (0.02 seedling /plot), *Dalbergia sissoo* (Sissoo) (0.04 seedling /plot), *Syzygium cumini* (Kalojam) (0.05 seedling /plot) showed lowest density in LNP (Table 1). These species showed highest density was not significant for food producing but comparatively density of food producing trees was less except *Artocarpus chaplasha* (Chapalish).

Highest relative density was found for *Artocarpus chaplasha* (Chapalish) (14.55%). *Erythsina variegata* (Mander) (7.37%), *Dysoxylum binectariferum* (Rata) (6.06%). *Grewia microcos* (Pitchli) (5.6%), *Syzygium fruticosum* (Gutijam) (4.76%), *Artocarpus lacucha* (Dewa) (3.64%) showed medium density respectively. The lowest relative density was found for *Vitex pubescens* (Awal) (0.09%), *Xglia kerrii* (Lohakat) (0.19%) followed by *Lophopetalum fimbriatum* (Rokton) (0.37%), *Syzygium cumini* (Kalojam) (0.56%), *Tamarindua indica* (Tetul) (0.65%), *Mangifera indica* (Am) (0.84%) etc species respectively (Table 1).

In contrast, the highest frequency and relative frequency were found for *Artocarpus chaplasha* (Chapalish) (52.73%) (9.75%). *Erythsina variegata* (Mander) (33.64%) (6.22%), *Dysoxylum binectariferum* (Rata) (33.64%) (6.22%). *Grewia microcos* (Pitchli) (32.73%) (6.05%), etc showed medium frequency and relative frequency (Table 1). The lowest frequency and relative frequency were found for *Tephrasia candida* (Bogamodula) (0.91%) (0.17%), *Lophopetalum fimbriatum* (Rokton) (2.73%) (0.5%), followed *Syzygium cumini* (Kalojam) (1.82%) (0.34%), *Mangifera indica* (Am) (6.36%) (1.18). Relative frequency and relative cover of *Artocarpus chaplasha* was the highest in LNP and had important sources of food for hoolocks (Ahsan, 2001). At present it observed that only in seedling stage; density, relative density, frequency and relative frequency of *Artocarpus chaplasha* were highest but in sapling stage its performance was not satisfactory due to climatic and anthropogenic causes.

Beside these, the highest abundance was found for *Dillinia pentagyna* (Hargoja) (4) followed by *Adinal polycephala* (Kumori) (3.5), *Syzygium cumini* (Kalojam) (3), *Butea monosperma* (Polash) (2.8) respectively whereas the lowest abundance was found for *Vitex pubescens* (Awal) (1) followed by *Dellenia indica* (Chalta) (1.16) respectively (Table 1). Among highest abundance only *Syzygium cumini* was fruit producing species and others trees species not important for Gibbons food. It is terrible news for Gibbons that food producing trees in LNP are replaced by other species. If replacement sprints continuously we will not see any Hoolock Gibbon after few decades in LNP.

Density of tree species in different diameter stages

In 0-2cm diameter range *Artocarpus chaplasha* (Chapalish) showed highest density (0.96 plants /plot) followed by *Grewia microcos* (Pitchli) (0.37 plants/plots), *Erythsina variegata* (Mander) (0.33 plants/plot), *Syzygium fruticosum* (Gutijam) (0.26 plants /plot) and lowest density showed *Bauhinia acuminata* (0.11 plants/plot) (Fig. 2). From 2-4cm diameter range *Artocarpus chaplasha* (Chapalish) was dominant (0.37 plants /plot). After that it followed *Erythsina variegata* (Mander) (0.25 plants/plot), *Dysoxylum binectariferum* (Rata) (0.16 plants /plot), *Thespesia populnea* (0.15 plants/plots) and the lowest density showed *Grewia microcos* (Pitchli) (0.05 plants/plots) (Fig. 2).

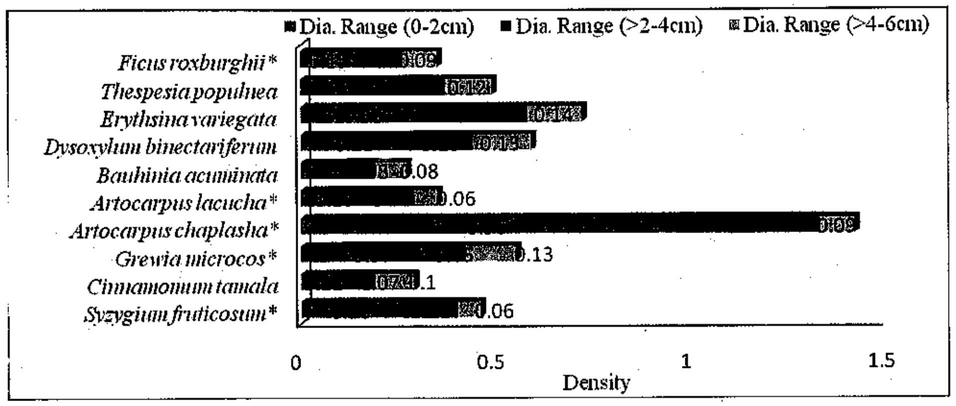

***Fig. 2:** Relation between density and diameter range (top 10 density species in LNP)*

Dysoxylum binectariferum (Rata) found highest density (0.15 plants /plot) between 4-6cm diameter ranges in LNP. The other species were followed by *Erythsina variegata* (Mander) (0.14 plants/plot), *Grewia microcos* (Pitchli) (0.13 plants/plots) and low density was seen for *Syzygium fruticosum* (Gutijam) (0.6 plants /plot), *Ficus roxburghii* (0.6 plants/ plot) respectively (Fig. 2).

At the seedling and sapling stage, maximum food trees species such as *Artocarpus chaplasha, Grewia microcos, Erythsina variegata* were dominant (Fig. 2). When reached in 4-6cm diameter (pole) then *Bauhinia acuminates Dysoxylum binectariferum* were dominant that's not significant to produce food for Hoolock Gibbon. However in small extent few trees produced food but most of them were seasonal. Yet, variation of climatic parameter effects on penology (time of flowering, fruiting, leaves falling, leaves flashing, seed germination, seedlings growth etc) that's another reason for poor regeneration and food shortage of gibbons. In natural forest (core zone) regeneration of *Artocarpus chaplasha* was highest but over statistics showed that *Erythsina variegata, Dysoxylum binectariferum, Grewia microcos* and *Syzygium fruticosum* will be dominated in LNP in future. If these species dominant in LNP it will threat not only for Hoolock Gibbon but also other wild animals.

Regeneration and seasonal variation of food producing tree species

Edible plant species richness provides better habitat quality and could be directly related to Hoolock Gibbon numbers. Diversity of fruiting trees is most important for Hoolock Gibbon survival (Ahsan, 2001, Feeroz, 2001). Regeneration patterns of fruits tree negatively altered due to climatic effect (certain variation in temperature, irregular rainfall, foggy condition, inconsistency in humidity, increase natural hazards, rapid change in soil pH and nutrients) and fasten growth of herbs, shrubs, vines etc (Philip, 2006). A variety of food species for hoolocks including *Artocarpus chapalasha*, *Syzygium* species, *Mangifera sylvatica*, *Ficus* species, *Grewia microcos*, and *Tamarindus indica* were represented in the sample plots in the park. Density of *A. chaplasha* (49%) was the highest in LNP among the food producing species. Others were *Syzygium* species (19%), *Ficus* species (14%), *Grewia microcos* (14%), *Mangifera indica* (2%), and *Tamarindus indica* (2%) respectively (Fig. 3). Fruits and flowers of *Artocarpus chapalasha* constitute an *important* component of the diet of hoolock gibbons (Ahsan, 2001, Feeroz, 2001, Islam et. al., 2006). But *Artocarpus chapalasha* was seasonal fruit trees and others important species also seasonal except *Ficus* species. So food deficiency was not a serious issue for decreasing of Hoolock Gibbon in LNP.

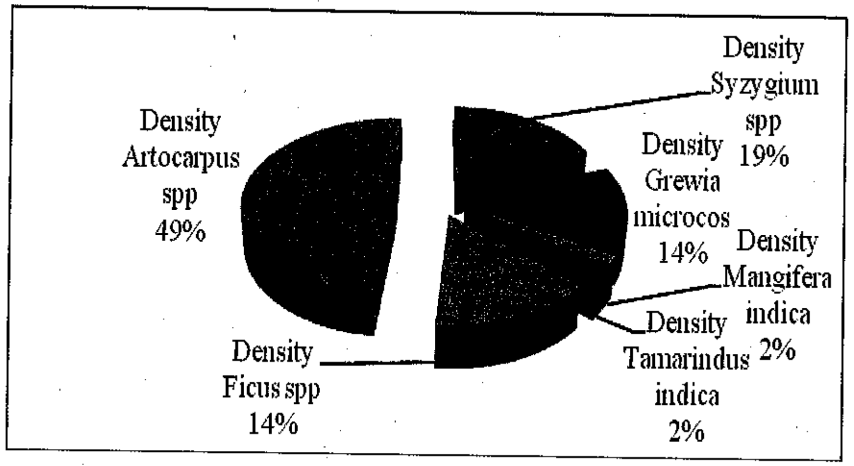

***Fig. 3:** Percentage of food trees regeneration (include seedlings, saplings and poles)*

Conclusion

The study concluded that key habitat feature of Hoolock Gibbon was associated with the edible plant species richness. For this reason regeneration is essential for preservation and maintenances of Hoolock Gibbon habitat. Due to climatic and anthropogenic causes regeneration trend of different tree species in LNP is changing. The rapid destruction and alteration of Hoolock Gibbon habitat by exotic tree species in LNP undoubtedly is the consequence in the extinction of the food trees species. As a result availability of food decreasing and threats for

Hoolock Gibbon persist. In Bangladesh Hoolock Gibbon can only survive if government commitments are translated into action and stringent measures are taken to protect and restore habitats. From regeneration viability assessments of different food species, following suggestions are provided to protect Hoolock Gibbon in LNP.

(i) Immediate cessation of deforestation in all the areas is required.
(ii) Plantation with important fruiting and close canopy sleeping trees in the habitat of *Hoolock hoolock* is suggested.
(iii) Plantation of diverse native tree species may be carried out on a large scale in a bid to restore degraded habitat where suitable.
(iv) Careful examination of all areas with *Hoolock hoolock* is also needed to assess the feasibility of translocation of doomed Gibbon populations into areas that are doing relatively better.

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Sustainability of Crop Production in Bangladesh: Challenges and Opportunities

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Abstract

Sustainability in crop agriculture may be defined as a concept that is agronomically productive, economically viable and relatively stable over years under adverse environmental stresses. Sustainability in crop production is vital because a) modern varieties very frequently are not capable of producing desirable yields under different stresses such as flood, drought, salinity and pests & diseases; b) high intensity of cropping depletes of soils nutrients and c) production is not often linked to post- harvest infrastructure. To ensure sustainability in crop production, mining of soil nutrients must be arrested; chemical fertilizers must be integrated with organic manures and bio-fertilizers and HYVs developed with tolerance to drought, flood, salinity, temperature and with resistance to pests and diseases. Farmers, small and marginal in particular must have an excess to adequate credit for better production. An Agriculture Credit Foundation following the model of PKSF should be established to meet credit needs of these farmers. Besides, farmers should be granted fair price of their produces through procuring foodgrains directly from them after harvest. It is also necessary to set up agro –based industries for processing and storage of food crops, specially perishable vegetables and fruits. Participation of farmers in need assessment, selection of appropriate technology and adequate farmer's training following bottom-up instead of top-down approach are the major issues in extension network that need to be addressed for sustainable production. Allocation of adequate fund to finance operational expenses in research is also important to generate new and sustainable technologies. It may be concluded that mere technological support is not sufficient to meet the twin challenges of enhancing and sustaining crop production. The production program must be linked to credit support and post- production parameters such as infrastructure and marketing network to ensure sustainability in production.

Introduction

The term sustainability is now-a –days linked to almost all activities related to development involving agriculture, education, industry, health and sanitation, etc. Sustainability in agriculture is an ability of an agricultural system to maintain its productivity when subjected to environmental and biotic stresses. The American Society of Agronomists (1998) defined sustainable agriculture as the one that over long term enhances environmental quality and resource base on which agriculture production depends, provides for basic human food and fiber needs, is

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economically viable and improves the quality of life for farmers and the society as a whole (Schneiderman and Carpenter,1990). The World Commission (1987) stressed the economic aspects of the sustainability by defining sustainable development as "economic development that meets the needs of the present generation without compromising the ability of future generations to meet their needs". Sustainable crop production may thus be defined as the concept that is agronomically productive, economically viable and relatively stable over years, specially under adverse environmental stresses.

A question arises why sustainability in crop production is necessary in Bangladesh? It is essential due mainly to the problems such as : a) modern varieties(MV) requiring high inputs, specially fertilizers and pesticides affect production environment/ base resulting in either stagnation or declining soil fertility and crop productivity, b) very frequently MVs developed by NARS institutes are not capable of producing desirable yield under different environmental stresses(drought, flood, salinity) and farmers thus suffer from yield loss almost every year (Santikarn et al.1991); c) high intensity of cropping involving MVs depletes nutrients of soils resulting in the declining soil fertility and d) modern technologies are often not linked to post-harvest infrastructure (processing, storage, marketing, etc.) and thus farmers are often deprived of fair prices of their produces that ultimately lead to low production of crops in next season/year.

In this paper, an attempt has been made to discuss key challenges and opportunities to sustainability of crop production in Bangladesh and make recommendations that may be useful to researchers, extensionists and policy makers in crop agriculture.

Challenges to Sustainability

a) Soil related constraints

Soil fertility decline

Soil fertility is declining due to intensive cropping, imbalanced use of fertilizers and very limited use of organic matter and micronutrients. It is reported that in Bangladesh major food crops remove about 2.98 m tons of nutrients annually against a total addition of 0.72 m ton only. This means that a significant declining in soil fertility is taking place due to continued depletion of soil nutrients. It is important to note that organic matter content of soil is much below the critical level of 1.5% (Karim, 1997). The deficiency of N is detected in all types of soils. Five million (m) ha land suffers from S deficiency and 2 m ha from Zn deficiency (Action Plan, 2000). Deficiency in B and Mo has also been reported in certain soils of the country.

Nutrient imbalance

The average use of mineral fertilizers is much below the recommended rates that can be attributed mainly to the resource limitation of the farmers, specially small and marginal. In most cases, more of N and less of P and K fertilizers are applied. Besides, very limited quantity of organic fertilizers is used. This results in imbalanced use of fertilizers that finally leads to low yield of crops.

Soil erosion and land loss

High rainfall, low organic matter in soils and poor soil management mainly contribute to soil erosion. About 1.74 m ha land is prone to soil erosion (Action Plan, 2000). It is alarming to note that about 1% crop land was lost during 2000-2010 due to various settlements (rural and urban), industrialization and soil erosion. Growth of rural settlement is the main reason for land loss from crop agriculture (Hasan et al. 2013). The loss of arable land poses a big threat to crop production and food & nutrition security of the country.

b) Constraints related to inputs

Insufficient water management

Water use efficiency in Bangladesh Agriculture hardly exceeds 30%. Considerable water is lost due mainly to faulty flood irrigation system (Mondal,2005).Harvesting and conservation of rain water during monsoon are virtually neglected even though it could become a good source for surface irrigation in dry season. Derelict ponds, specially of Barind area that could be utilized for harvesting rain water for irrigation are reported to be encroached by the influentials belonging to different political parties. Other challenges include lowering of water table, its contamination of ground water by heavy metals (Cd, Pb,As, etc.) and rise in salinity of surface and ground water in the coastal region of the country. Besides, irrigation cost in Bangladesh is very high due mainly to high price of diesel and electricity. It may also be noted that more than 80% of irrigation pumps in Bangladesh are run by diesel. According to a report of IRRI, irrigation cost in Bangladesh is $117.60 per ha compared to $25.55 in India, $17.94 in Thailand and $17.98 in Vietnam (Dey et al.2013).

Shortage of quality seeds

Of the total seed requirement, only 6% seeds are supplied by BADC (Huda, 2004). Contribution of private traders and NGOs to the seed supply is negligible. Supply of insufficient quantity of quality seeds and their high prices are some of the major constraints in seed production program. Besides, Seed Certification Agency (SCA) that is responsible for testing seeds for quality is plagued with problems like very limited manpower & equipment and frequent deputation of officers from the Department of Agricultural Extension (DAE).

Inadequate credit

Majority of farmers, specially small and marginal cannot afford high management cost for crop production. They also have low and very limited access to institutional credit because of collateral requirement. They are not eligible for microcredit of NGOs either that mainly deal with landless farmers. Besides, weekly installment-based credit recovery of NGOs is not suitable for crop agriculture. They often cannot purchase inputs required for better production due to resource constraints. The situation compels them to use limited quantity of inputs, specially P& K fertilizers that finally lead to low yield (Mondal, 2010).

c) Environmental stresses

Flood, drought and salinity

Crop production and productivity in Bangladesh is constrained by environmental stresses such as flood, drought and salinity. Approximately, 1.23 and 5 m ha of crop lands become severly and moderately flood prone respectively. Likewise, droughts of different intensity occur in different seasons in the country annually. About 2.5 m ha land in kharif season and 1.2 m ha in dry season are affected by drought (Action Plan, 2000). During kharif 2 season, T.aman is affected by drought specially at grain filling stage that results in significant reduction in yield. Besides, about 1 m ha land in the coastal area is affected every year by different degree of salinity (Karim, 1997). Other challenges of climate change are the rise in temperature, CO_2 concentration and low radiation. Temperature rise due to global warming would decrease the yield of boro rice by 55-60% and wheat by 61% by 2050 (New age, 2008). Facts remain that limited technologies are available that are tolerant to these climatic stresses.

Pests and diseases

Favourable climate of the country encourages the incidence and multiplication of pests resulting in yield loss of crops every year. Intensification of cropping also contributes to the incidence of pest population. It is estimated that 4-14% rice yields in Bangladesh is lost every year by insect pests. Other constraints are the limitation in the number of resistant/ tolerant varieties of crops and the use of IPM technology. The IPM technology is still confined to rice and few vegetables (Mondal, 2005). Likewise, the use of pheromone technology effective in controlling shoot and fruit borers in brinjals and white fly in cucurbits at field level is still very limited (Alam et al. 2008).

Temperature

High temperature accompanied by low or no rainfall accentuates severity of droughts, specially at the later part of kharif 1 causing considerable yield loss of crops. High temperature at the grain filling stage is also reported to cause sterility and thereby yield loss in rice, wheat and mustard. Yield of wheat in particular is reduced due to short and less winter in the country (Eunus, 2001). In addition, high temperature in the later part of February and March that favours incidence of pests and diseases also reduces yield of pulses, potato, vegetables, etc.

d) Infrastructural constraints

Insufficient roads, markets, etc.

Major problems are inadequate roads, markets, high price risks and lack of credit to traders for marketing activity and processing & storage. These factors finally lead to high transport cost for selling produces, and buying necessary inputs. Other key problems include low capacity utilization, irregular supply of necessary raw materials, high marketing and handling cost, high price of packaging materials and lack of suitable cold storage facilities for perishable fruits and vegetables. Due to these problems, the industries are not able to process the seasonal surpluses and provide stable price support to farmers for their produces (Mondal, 2005).

Low prices of produces

Small and marginal farmers that constitute bulk of the farm population are generally resource poor. They normally are have to sell their produces after harvest to repay their outstanding loan. They cannot store their produces due to lack of storage facility at their level. They are thus compelled to sell their produces at lower prices to the intermediaries. It may be mentioned that the government procured only 20% rice (boro and aman) from farmers and the rest 80% from millers and traders during 1991-2012 (Alam, et al.2013). Since these farmers are often unable to meet the procurement requirement (14% moisture content in rice, etc.), they cannot sell their produces rice and wheat in particular to the government at the prices fixed by the latter (Mondal, 2010). It may be noted that during the last few years or so, farmers have been selling their paddy at a price much lower than the production cost. The situation may finally force them to cultivate profitable non-cereal crops. The shift will certainly be a threat to national food security.

e) Constraints related to cropping pattern

Imbalanced cropping pattern

Cropping patterns are still highly dominated by cereals even though other crops like oilseeds, pulses, vegetables, etc. are also vital to meet nutrient needs of the increasing population of the country (Eunus, 2001). As a result, people in general have little scope to consume nutrient-rich foods and, therefore, seriously suffer from malnutrition.

f) Problems in research and extension

Investment in agricultural research in Bangladesh now stands at only 0.2% of GDP (Karim, 1997). Scope for promotion and training of scientists are limited mainly due to fund constraint. Moreover, a number of trained and skilled scientists had left NARS institutes for better opportunity elsewhere (Mondal, 2010).

Top-down approach in technical issues such as least participation of the farming community in need/problem identification, technology selection and inadequate farmers' training in production and post-production technologies are some of the major constraints in extension (Actionable policy implications, 2004). Besides, linkage between research and extension is still weak. This weakness serves to limit realization of full potential of a new technology. The Technology Transfer and Monitoring Unit (TTMU) of BARC responsible for establishing the linkage is virtually inactive. In addition, National Agricultural Technology Coordination Committee (NATCC) has remained dysfunctional for years (Strategic Plan, 1995).

Opportunities for Sustainability

a) Soil and fertilizer management

Mining of soil nutrients occurs on a continued basis resulting in decline in its fertility. Therefore, it is essential to prevent mining of soil nutrients to maintain soil fertility. The present land use policy of the government should also the reviewed and enacted to stop land loss without further delay. Neither mineral fertilizers nor organic matter alone could produce yield on a sustainable basis. Mineral fertilizers need to be integrated with organic and biofertilizers through integrated plant nutrient system (IPNS). Methods to improve N efficiency (split application, use of USG and time of application) developed for rice and wheat should be expanded to include other crops like oilseeds, pulses, tubers and vegetables. Besides, research should be undertaken on the use of green manures to different crops, kind of nutrients and organic matter build-up in soils and their effects on soil fertility and crop productivity in different AEZs of the country. In many areas of Bangladesh including the hills, erosion of top fertile soils is a big challenge. Future research should thus be undertaken to assess the annual soil loss from erosion-prone areas and develop appropriate soil conservation practices. More studies are also necessary on the effects of B fertilizer, specially on crops like wheat, mustard, chickpea and groundnut to reduce grain sterility (Mondal, 2005).

b) Input supply and management

Quality seeds

About 6% of the total requirements of seeds are certified quality seeds. If 20% of the requirements are to be met through quality seeds, the current seed production programs needs to be strengthened substantially. To achieve the objective, the present breeder seed production of NARS institutes should be expanded rapidly. Besides, BADC's present capacity for seed production needs to be raised through strengthening its seed multiplication farms in drying, storage and processing facilities. In addition, the private sector and NGOs need to be supported in the production of quality seeds through necessary credit supply and provided necessary training (Mondal, 2010) .The SCA should as well be strengthened as an independent body in terms of manpower and equipment. Adequate fund should also be allocated to SCA for training and seed testing. It is to be noted that a target has been fixed by the government to produce 20% of the total seed requirement by 2014-2015 at public and private sectors (Actionable policy implications, 2004).Efforts are necessary to achieve the target soon.

More than 90% of the seeds of different crops are still produced by farmers themselves. The farmers need to be given training in the production, drying, processing and preservation of seeds and provided credit support for post-harvest operations. Different seed dealers and traders should also be urged to make quality seeds available in time, in adequate quantity and at fair price to the farmers.

Water management

In Bangladesh, the water use efficiency is around 30% only. This calls for further studies on the scheduling of irrigation based on water requirement and appropriate growth stages of crops as a priority. Water management program may be strengthened by adopting alternate wetting and drying (AWD) method in rice instead of flood irrigation. Harvesting of rain water during monsoon and its conservation by re-excavating canals, derelict ponds and other water bodies should also receive priority attention for supplementary irrigation to T.aman and irrigation to dry season crops. The water bodies encroached by the influential should, however, be recovered to use surface water from these sources for irrigation. Necessary regulations should also be formulated and enforced for efficient use of irrigation water. Conjunctive use of ground and surface water should be promoted through augmentation of surface water availability (Action Plan, 2000; NAP, 2010). Irrigation cost in Bangladesh constitutes a major part of production cost due mainly to high price of diesel and electricity. Therefore, uninterrupted supply of electricity and timely availability of diesel at least at 20% subsidy for irrigation are essential to sustain crop production. It is worth noting that irrigation costs are highly subsidized in India, Thailand and Vietnam (Actionable policy implications, 2004).

Attempts are also needed to grow crops using residual soil moisture through minimum tillage, relay cropping and intercropping practices. Besides, cultivation of low water requiring crops (wheat, pulses, etc.) may be promoted to reduce dependence on ground water for irrigation.

Supply of agriculture credit

For sustaining production and ensuring food security, small and marginal farmers in particular must have access to credit facilities. The credit institutes of the country are not unfortunately structured to disburse credit to these farmers. In the circumstances, a new institution in the name of Agriculture Credit Foundation following the model of PKSF needs to be established to cater to the needs of these farmers (NAP, 2010; Khandker et al.2013). These farmers must have access to credit without any collateral requirement. Such credit should, however, be disbursed before planting and realized after the harvest of the crops (crop season-based credit).

c) Adaptation to environmental stresses

Flood, drought, salinity and temperature

Bangladesh Rice Research Institute (BRRI) has by now developed salt tolerant varieties such as BRRI dhan 40,41,47,53 and 54. The institute has as well developed BRRI dhan 51 and 52 with tolerance to submergence for about 2 weeks. Besides, BRRI dhan 42 and 43 having tolerance to drought have been developed. Likewise, Bangladesh Agricultural Research Institute (BARI) has released few heat-tolerant varieties of wheat, namely BARI gom 21, 22, 23 and 24.These varieties are suitable for late planting because of their tolerance to heat that generally occurs from late February onward. The varieties should now be disseminated at farm level after necessary on-farm trials. Cultural practices like early planting, minimum tillage, intercropping and mulching and short duration varieties are also available to manage drought and flood. Greater research thrusts are, however, essential to develop crop varieties tolerant to drought, salinity and flood. Similarly, ridge –furrow and sorjan cropping is being practiced by farmers to manage salinity. Further field trials are, however, necessary to refine these practices (Mondal, 2005). Wheat, mustard and rice suffer from grain sterility due to high and low temperature almost every year. The problem should be addressed by planting the crops early or in optimum time. It is also important to evolve greater number of heat-tolerant varieties of these crops.

Pests and diseases

Both conventional breeding and biotechnology should be used to develop more varieties resistant to pests. It is also extremely vital to expand IPM technology to other economic crops like oilseeds, pulses, fruits and spices (Mondal, 2010).

BARI has developed sex pheromone technology to control shoot and fruit borers in brinjals and white fly in cucurbits (Alam et al. 2008). Necessary steps should now be taken to transfer the technology at field level. Crop production in a sustainable manner calls for these integrated approaches to pest management.

d) **Post-harvest operations and infrastructure**

Crop production cannot be sustained unless production programs are linked to different post-harvest operations and marketing network. Local Government Engineering Department (LGED) has built rural roads, bridges and culverts but these are not sufficient to meet the needs of different producers. Therefore, present marketing network needs to be improved by reducing the interventions of the intermediaries (millers and traders) and developing the present markets and constructing new ones. Different storage facilities should as well be established in rural areas which may allow farmers to store their produces temporarily and sell the same at better prices when the demand is high. In addition, farmers should be granted fair price of their produces through procuring bulk of foodgrains directly from them after harvest by setting up procurement centers at union levels. To make the procurement program effective, the present ceiling of 4-6% should be raised to at least 10% of the total production. Such program may be expanded to include other crops like pulses and oilseeds. Farmers may also be organized to form Farmers' Association or Community- based organization that may enable them to bargain for fair prices of their produces (Action Plan, 2000). It is also essential to set up more agro-based industries for processing and storage of perishable fruits and vegetables in particular to ensure fair price to growers and thereby sustainability in crop production. Such entrepreneurs need to be provided with necessary credit support by the government to set up the industries (Mondal, 2005).

e) **Improvement of cropping patterns**

Present cropping patterns are traditionally dominated by cereal crops. Lately, pulses have been introduced into the patterns. However, place of vegetables, oilseeds and fast-growing fruits in the patterns is still very weak. Research thrust should thus be needed to introduce these crops into the cropping patterns. The introduction is likely to make these nutrient-rich crops available, specially to resource –poor farmers and may thus help them improve their intake of these nutrient-rich foods.

f) **Research and extension programs**

To ensure sustainable production, research programs of NARS institutes must be reoriented to develop technologies to address different environmental and biotic stresses. It is also important to provide sufficient fund allocation to finance operational expenses in research and provide adequate incentives specially for the retention of trained and innovative scientists. This will certainly encourage the scientists to generate new technology(s). Participation of farmers in need assessment, selection of new technology and adequate farmers' training in production and post-production technology following bottom-up approach instead of top-down are some of the major issues in extension network that need to be adequately addressed for sustainability in crop production (Actionable policy implications, 2004). Adoption of community-based extension approach will benefit all groups of farmers including small and marginal (NAEP, 1996).

Conclusion

Technological support alone is not sufficient to meet the twin challenges of enhancing and sustaining crop production. The production programs must be closely linked to socio-economic parameters. It is also necessary that such programs are linked to credit support and post- production parameters such as infrastructure and marketing network to ensure sustainability in production. A special/new credit institution should be established to cater to the needs of small and marginal farmers in particular. Marketing network should be strengthened by reducing the interventions of intermediaries (millers and traders) and improving market infrastructure. Farmers must as well be ensured fair price of their produces by procuring foodgrain directly from them after harvest. Greater number of agro-based industries must also be set up for processing and storage of vegetables and fruits. The step will enable the growers to obtain fair price of their produces and ensure sustainability in crop production.

Recommendations

- Mining of soil nutrients is still occurring on a continued basis. It is therefore, extremely vital to prevent mining soil nutrients to restore soil fertility. It is also necessary to integrate chemical fertilizers with organic manures and biofertilizers through IPNS to ensure sustainable crop production.
- Water use efficiency must be enhanced by strengthening the present water management programs. To achieve this, conjunctive use of ground and surface water needs to be promoted through the augmentation of surface water availability. Harvesting of rain water and its conservation by re-excavating canals and other water bodies should receive priority for surface irrigation. It is, however, necessary to recover the waterbodies from the encroachers. Appropriate efforts are also necessary to exploit residual soil moisture through minimum tillage, relay cropping, intercropping and mulching practices to grow different crops.
- A target has been fixed by the government to produce 20% of the total seed requirement by 2014-2015 at public and private sectors. If this requirement is to be made, the current seed program of BADC and breeder seed programs of NARS must be strengthened. Adequate fund

allocation should as well be given to SCA for seed testing and training of farmers and its manpower.

- For ensuring sustainability in production and food security, farmers specially small and marginal must have excess to credit facility. The credit institutes of the country are not, however, structured to benefit these farmers. Therefore, an Agriculture Credit Foundation following the model of PKSF should be established to cater to the needs of these farmers. Such credit should be disbursed well ahead of planting and realized after the harvest of crops.
- Greater research thrust is recommended to develop crop varieties with tolerance to environmental stresses such as flood, drought and salinity. It is also necessary to develop more heat- tolerant varieties of crops, wheat, mustard and rice in particular. Use of cultural practices like early planting, minimum tillage, intercropping, relay cropping and mulching is also essential to address drought and flood.
- IPM technology is still confined to rice and few vegetables. The technology should be expanded to other economic crops. An initiative should as well be taken to disseminate the sex pheromone technology at field level.
- A crop production program cannot be sustained unless it is linked to marketing network. The network should, therefore, be strengthened by reducing the interventions of intermediaries (millers and traders) and improving the present market infrastructure.
- Farmers must be granted fair price of their produces through procuring foodgrains by the government directly from them after harvest by setting up procurement centers at union levels. Farmers may also be organized to form Farmers' Association that may enable them to bargain for fair prices of their produces.
- It is also important to set up more agro-based industries for processing and storage of food crops, specially perishable fruits and vegetables to ensure fair price to the growers.
- Sufficient fund must be allocated to NARS institutes to finance operational expenses in research and provide adequate incentives, specially for the retention of innovative and talented scientists. The initiative will certainly encourage the scientists to generate new and sustainable technology(s).
- Participation of farmers in need assessment, selection of new technology and adequate farmer's training following bottom-up instead of top-down approach in extension network is strongly recommended to ensure sustainability in crop production.

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Florestic Composition of a Protected Area of Dudpukuria-Dhopachari Wildlife Sanctuary, Chittagong, Bangladesh

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Abstract

Floristic composition of a Protected Area of Dudhpukuria-Dhopachori Wildlife Sanctuary in Chittagong, Bangladesh was assessed in 2011 following whole area survey method. A total of 609 plant species belonging to 392 genera and 116 families were recorded and the species were categorised to tree, shrub, herb, climber, fern, epiphyte and parasites. Magnoliopsida, Liliopsida and Pteridophytes were represented by 431, 161 and 17 species respectively, where 28 species were categorized as exotic. Among the families of Magnolipsida, Rubiaceae represents the maximum 38 species and 25 genera. In Liliopsida, Poaceae appeared as the dominant family having 34 genera and 53 species; whereas the pteridophytes represent maximum 3 species in Polypodiaceae. Considering the conservation status, the plant species were classified into seven (7) catgegories, where maximum (359) number of species was found as Least Concerned (LC) and 42 plant species were threatened. Among the six major use categories (timber, food and fodder, fuel, medicine and miscellaneous), 242 species were used for medicine, whereas timber and 'food and fodder' yielding plant species were 102 and 164 respectively.

Key words: *Biodiversity, Floristic composition, Dudhpukuria-Dhopachori, Wildlife Sanctuary, Conservation*

Introduction

Awareness and interest regarding biodiversity is increasing day by day because of its role in maintaining balanced ecological functions in our natural environment. Bangladesh possesses a rich biological heritage of flowering plants (Hossain 2001, Barua *et al.* 2001, Nishat *et al.* 2002). Plant resources are one of the most important elements of biodiversity which support life system on earth (Hossain *et al.* 2009). Records show that 3611 species of angiosperms are available in the forests of Bangladesh (MoEF 2010) of which some 2,259 species are reported from Chittagong region alone (Khan *et al.* 2008). But, these plant genetic resources have not been well studied, and so far, only a few species have ever been evaluated for their medicinal, horticultural, and agricultural potentials

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(Hossain *et al.* 2009). There is a loss of plant genetic resources in Bangladesh (Razzaque and Hossain 2007), but the extent is not known exactly. A total of 22 endangered plant species was reported in Bangladesh (Banik 1992), whereas threatened vascular plant species were 106 (Khan *et al.* 2001).

Knowledge of forests structure and floristices are necessary for the study of forest dynamics, forest management, biotic interactions and nutrient cycling in the concerned area. Biodiversity is investigated in order to conserve and maintain them in their natural habitats (Pielou 1995). Much of the biodiversity in tropical forests resides in herbs, shrubs and small trees (Nath *et al.* 2000). In Bangladesh, it is urgent to effectively protect and manage the existing natural forests for future generations (Hossain 2004). Information on the species composition of a forest is essential for its wise management in terms of economic value and regeneration potential (Wyatt-Smith 1987). It is also important for management and improvement of wildlife of the country. The Dudhpukuria-Dhopachari Wildlife Sanctuary, formerly a part of the reserved forest of Chittagong South Forest Division, was designated a Protected Area on 6th April, 2010 by the government of Bangladesh. Deforestation and encroachment has already destroyed a significant portion of this sanctuary during the last decades. Forest Department (FD) and Integrated Protected Area Co-management (IPAC) initiated their co-management project in that area. But, there is no published basic quantitative information on the composition and structure of the vegetation of Dudhpukuria-Dhopachari Wildlife Sanctuary. The present study is, therefore, first attempt to assess and analyse the entire plant genetic resources of Dudhpukuria-Dhopachori wildlife sanctuary based on copious field observations and herbarium data in order to contribute to the overall knowledge of Bangladesh flora and management of the wildlife sanctuary. Results of the study will help to undertake species specific special conservation measures for the threatened or rare plants. The uses of the recorded plants in this study will also suggest probable presence of some wildlife species, enrichment plantation of fodder species and status of Dudhpukuria-Dhopachori wildlife sanctuary as wildlife habitat.

Materials and Methods

The study was carried out in the Dudhpukuria-Dhopachori Wildlife Sanctuary (DDWS) that lies at south-eastern side of Bangladesh between 22°09′ to 22°22′ north latitude and 92°05′ to 92°10′ east longitudes along the borderline of Chittagong, Rangamati and Bandarban districts. Climate of this area is typically subtropical, with a long dry season extending from October to April. From June to September, the south-west monsoon provides the majority of the average rainfall of about 1,611-3,878 mm. Temperature and humidity ranges from 7.2°C – 25.1°C and 67% - 88% respectively round the year (Banglapedia, 2006). The present landuse categories of Dudhpukuria-Dhopachori Wildlife Sanctuary in relation to the area are dominant with natural forest (Table 1).

Table 1: Landuse categories of Dudhpukuria-Dhopachari WS (IRG 2011).

Landuse categories	Area (ha)
Natural Forests	3,874.2
Long rotation plantations (excluding Teak)	286
Short rotation plantations	41
Teak plantations	112.8
Agar plantations	90
Bamboo plantations	79
Cane plantations	187
Encroachment of the forest land	46.6
Total	4716.6

The Wildlife Sanctuary (WS) comprises the Reserved Forests of three beat namely Dudhpukuria (830 ha), Dhopachori (2996 ha), and Kamalachari (891 ha) under the jurisdiction of Khurusia and Dohazari Forest Ranges of Chittagong (South) Forest Division. Almost the whole area of Dudhpukuruia and Kamalachari and a major part of Dhopachori is represented by natural reserve forest (Feeroz *et al.* 2012). The whole wildlife sanctuary area, criss-crossed by numerous creeks, is comprised of hill and hillocks (about 80% of total area) and plain lands (about 20% of total area) covered with forests and grasses.

For assessing the floristic composition of the study area, field work was conducted through Whole Area Survey method from April, 2010 to December, 2011 following Reddy and Pattanaik (2009) and Malaker et al. (2010). Field work was scheduled in such a way that will enable plant specimen collections and field observations during the flowering and fruiting time of maximum number of species. A total of 12 foot trails of substantial length (approximately 42.5 km) in three beats of DDWS were surveyed for the assessment of floristic composition. Survey work was continued until occurrence of new species. All the plant species were identified, recorded and tagged in the field. Herbarium specimens of unknown and rare plants were prepared following standard scientific method with fertile materials (flower, fruits and seeds) but, specimens without fertile material were also collected for herbarium preparation in case of their unavailability. Herbarium specimens were than identified with the help of taxonomists and Dry Wood Preservation Laboratory of Bangladesh Forest Research Institute. After study thery were preserved in the Seed Research Laboratory of the Institute of Forestry and Environmental Sciences, Chittagong University. Conservation status (i.e. least concern, threatened etc.) and uses of the identified plants were assessed following Encyclopeida of Flora and Fauna of Bangladesh (Ahmed et al. 2008).

Results and Discussion

Floristic composition

The study reveals that Dudpukuria-Dhopachori Wildlife Sanctuary harbours 609 plant species belonging to 392 genera and 116 families of seven different

categories, viz. tree, shrub, herb, climber, fern, epiphyte and parasites (Appendix 1). Herbs constitute the major category (200 species, 130 genera and 41 families) of plant community followed by trees (183 species, 125 genera and 48 families), shrubs (125 species, 96 genera and 39 families), climber (71 species), fern (17 species), epiphytes (7 species) and parasites (6 species) (Fig. 1).

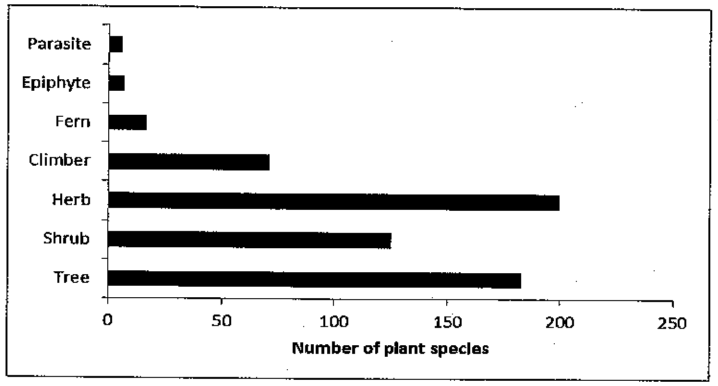

***Fig.1.** Number of different categories of flora in Dudpukuria-Dhopachari WS*

Among the 609 species, Magnolipsida comprise a total of 431 species under 281 genera and 84 familiy, Lilipsida comprise 161 species under 98 genera and 21 family and Pteridophytes comprise 17 species under 13 genera and 11 family. In Magnoliopsida (Diocotyledons), Rubiaceae appears to be the largest family (Table 2) having 25 genera and 38 species followed by Euphorbiaceae (15 genera and 36 species), Fabaceae (17 genera and 33 species) and Asteraceae (13 genera and 16 species). In Liliopsida (Monocotyledons), Poaceae appears to be the largest family having 34 genera and 53 species followed by Cyperaceae (14 genera and 40 species), Araceae (9 genera and 12 species) and Arecaceae (8 genera and 11 species). A significant number of Pteridophytes comprising 17 species under 13 genera and 12 families were also recorded from the study area. Among the Pteridophytes, family Polypodiaceae possesses 3 species and Pteridaceae, Lygodiaceae, Adiantaceae contain two species each. Among the 115 families of the study area 46 families were represented by only one species (Table 2).

Table 2: Angiosperms with their family, genera and species numbers.

Family	Genus No.	Species No.	Family	Genus No.	Species No.
			Magnoliopsida		
Acanthaceae	6	6	Leeaceae	1	3
Alangiaceae	1	1	Loranthaceae	3	3
Amaranthaceae	6	8	Lythraceae	2	4
Anacardiaceae	6	7	Magnoliaceae	1	1
Annonaceae	2	2	Malvaceae	5	8
Apiaceae	1	1	Melastomataceae	2	2

Family	Genus No.	Species No.	Family	Genus No.	Species No.
Apocynaceae	10	11	Meliaceae	8	11
Aquifoliaceae	1	1	Menispermaceae	2	2
Araliaceae	1	1	Mimosaceae	5	10
Aristolochiaceae	1	1	Moraceae	5	16
Asclepiadaceae	8	8	Myristacaceae	1	1
Asteraceae	13	16	Myrsinaceae	3	6
Bignoniaceae	3	4	Myrtaceae	2	10
Bombacaceae	1	1	Ochnaceae	1	1
Boraginaceae	3	3	Olacaceae	2	2
Buddlejaceae	1	1	Oleaceae	2	4
Burseraceae	2	2	Passifloraceae	1	1
Caesalpiniaceae	5	14	Piperaceae	1	2
Campanulaceae	1	2	Plumbaginaceae	1	1
Capparaceae	2	2	Polygalaceae	1	1
Celastraceae	1	1	Polygonaceae	1	1
Ceratophyllaceae	1	1	Proteaceae	1	1
Clusiaceae	2	4	Ranunculaceae	2	2
Combretaceae	4	8	Rhamnaceae	1	2
Connaraceae	2	2	Rhizophoraceae	1	1
Convolvulaceae	8	16	Rubiaceae	27	38
Crypteroniaceae	1	1	Rutaceae	7	7
Cucurbitaceae	3	3	Sapindaceae	4	5
Cuscutaceae	1	2	Sapotaceae	1	1
Datiscaceae	1	1	Scrophulariaceae	2	3
Dilleniaceae	1	2	Simaroubaceae	1	1
Dipterocarpaceae	5	7	Solanaceae	2	3
Ebenaceae	1	2	Sonneratiaceae	1	1
Elaeagnaceae	1	1	Sphenocleaceae	1	1
Elaeocarpaceae	1	3	Sterculiaceae	4	7
Euphorbiaceae	15	36	Theaceae	2	2
Fabaceae	17	33	Thymelaeaceae	2	2
Fagaceae	1	4	Tiliaceae	4	8
Flacourtiaceae	2	2	Ulmaceae	1	1
Juglandaceae	1	1	Urticaceae	2	2
Lamiaceae	3	5	Verbenaceae	8	12
Lauraceae	6	7	Vitaceae	5	7
Liliopsida					
Alismataceae	1	1	Lemnaceae	1	1
Aponogetonaceae	1	2	Liliaceae	2	2
Araceae	9	12	Marantaceae	2	2
Arecaceae	8	11	Musaceae	1	1
Commelinaceae	5	8	Orchidaceae	6	6
Costaceae	1	1	Pandanaceae	1	1
Cyperaceae	14	40	Poaceae	34	53

Family	Genus No.	Species No.	Family	Genus No.	Species No.
Dioscoreaceae	1	6	Pontederiaceae	1	2
Haemodoraceae	1	1	Smilacaceae	1	1
Hydrocharitaceae	1	1	Zingiberaceae	6	8
Juncaceae	1	1			
Pteridophyte					
Adiantaceae	1	2	Lygodiaceae	1	2
Angiopteridaceae	1	1	Polypodiaceae	3	3
Athyriaceae	1	2	Pteridaceae	1	2
Gleicheniaceae	1	1	Sinopteridaceae	1	1
Helminthostachyaceae	1	1	Stenochlaenaceae	1	1
Lindsaeaceae	1	1			

Tree species: 183 tree species were recorded in the DDWS, where Euphorbiaceae represented by the highest number of species (17) and genera (11) followed by Rubiaceae (13 species and 11 genera), Moraceae (13 species and 3 genera), and Meliaceae (11 species and 8 genera).

Shrub species: 125 shrubs were recorded in the DDWS. Among the 39 families, Rubiaceae possessed the highest number of species (20) and genera (13) followed by Euphorbiaceae (13 species, 8 genra) and Fabaceae (13 species, 7 genera).

Herbs: Herbs constitute the dominant proportion of total plant communities (200 species). Among the all 41 families, Poaceae represents highest number of species (46) and genera (29) followed by Cyperaceae (40 sepcies, 14 genera) and Asteraceae (14 species, 12 genera).

Climbers: Similar to the natural forest patches of Bangladesh and also of tropical forests, a number of climbers are common in the Dudpukuria-Dhopachari WS. Convolvulaceae family represents the maximum number of species (14) and genera (7) followed by Fabaceae (10 species, 7 genera) and Arecaceae (5 species, 2 genera). Most common climbers are *Daemonorops jenkinsiana, Mikania cordata, Caesalpinia bonduc, Dioscorea pentaphylla, Tragia involucrata, Dioscorea aculeata, Vigna adenantha, Entada rheedii, Operculina turpethum, Merrimia umbellata* etc.

Ferns: Forest floor of the DDWS was also moderately rich in fern communities. *Drynaria quercifolia, Angiopteris evecta, Blechnum orientale, Lygodium flexuosum* are some of the most common ferns of the WS area.

Epiphytes: *Aerides multiflora, Staurochilus ramosum, Dendrobium fimbriatum* are some of the mostly occurred epiphytes in DDWS.

Parasites: Loranthaceae was represented by 3 species of parasites under 3 genera followed by Cuscutaceae (2 species and 1 genus). *Hoya parasitica, Helixanthera parasitica* were common in the DDWS area.

Exotic to naturalized species: A total of 28 species belonging to 25 genera and 19 families were identified as exotic to naturalize among the recorded 609 angiospermic species of DDWS. Among these, 13 herbs, 12 trees and 3 shrubs were common. *Acacia auriculiformis, Acacia mangium, Ageratum conyzoides, Chromolaena odorata, Hyptis suaveolens, Lantana camara* L. var. *aculeata, Scoparia dulcis, Senna siamea, Tectona grandis* etc. are some of the major exotic plants found in Dudhpukuria-Dhopachori Wildlife Sanctuary.

Vulnerability of the plant species: Vulverability of the available plants were assessed following the Encyclopedia of Flora and Fauna of Bangldesh (Ahmed *et al.* 2008). The categories viz. Conservation Dependent (CD), Endangered (EN), Least Concerned (LC), Lower Risk (LR), Not Evaluated (NE), Not Evaluated but seems to be rare (NER), Near Threatened (NT) and Vulnerable (V) were represented by 66 (11%), 4 (0.7%), 359 (59%), 3 (0.5%), 69 (11%), 47 (8%), 23 (4%) and 38 (6%) plant species respectively, where number of Least Concerned (359, 59%) species was maximum (Fig. 2). A total of 42 threatened plant species were found in the protected area, where 38 species were Vulnerable (V) and 4 were Endangered (EN). Some of the important threatened species are *Brownlowia elata, Calamus guruba, Calamus latifolius, Lithocarpus acuminata, Mangifera sylvatica, Spatholobus acuminatus, Swintonia floribunda, Terminalia arjuna, Terminalia chebula* need immediate conservation initiatives.

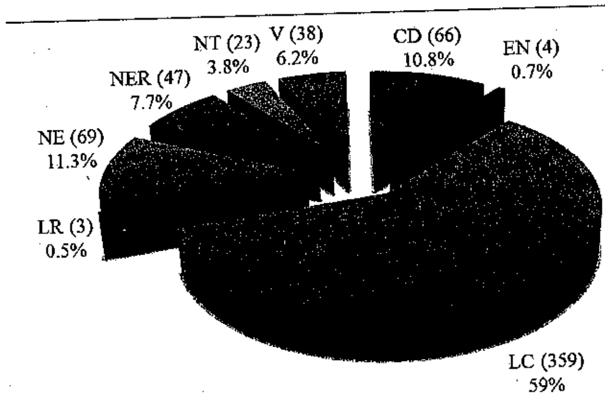

Figure 2. Distribution of the recorded plants of DDWS into different conservation categories
[*CD = Conservation Dependent, EN = Endangered, LC = Least Concerned, LR = Lower Risk, NE = Not Evaluated, NER = Not Evaluated but seems to be rare, NT = Near Threatened and V = Vulnerable]

Use of plants by the local people of the DDWS

Five major use categories of the plant species (timber, fuelwood, food and fodder, medicine and miscellaneous) were considered for the recorded plant speices of Dudhpukuria-Dhopachori WS (Table 3). About 242 species (39.7% of all

species) were found to be used as medicine. The food and fodder providing plants were 164 (26.9% of all species), where 102 tree species possess timber value. The category namely miscellaneous includes plant species that yields tannins, resins, oils, ornamental value, used in cottage industries etc. (Table 3).

Table 3: Distribution of plants under different use categories in relation to their habit form.

Use category	Tree	Shrubs	Herbs	Climber	Ferns	Epiphytes	Parasites	Total
Timber	102							102
Fuelwood	33	5		1				39
Food and fodder	61	21	70	8	4			164
Medicine	77	56	74	27	5	1	2	242
Miscellaneous	70	39	53	11	6	5		184

Bangladesh is rich with a variety of crops, fruits, nuts and forest plants covering a wide array of species and genera. According to the people living around the forest, the study area once was rich in vegetation coverage and species composition, but disturbed heavily in the recent past. However, the Wildlfie Sanctuary currently harbours higher number of plant species (609 species, 319 genera and 115 families) in comparison to the 422 vascular plants of Chunuti WS (Khan and Huq 2001); 374 species, 264 genera and 84 families of Lawachara National Park (Uddin and Hassan 2010); 151 species, 127 genera and 49 families in Lalmai hills of Comilla (Hossain *et al.* 2005); 187 species, 160 genera and 65 families of Ghagotia union of Gazipur (Alam *et al.* 2006) and 174 species, 131 genera and 51 families of Madhupur sal forest (Malaker *et al.* 2010). Similarly, 85 tree species belonging to 30 families were recorded from Bamu reserve forest of Cox's Bazar (Hossain *et al.* 1997), and 85 tree species having ≥10 cm dbh belonging to 36 family and 68 genera was reported from Sitapahar Reserve Forest (Nath *et al.* 2000). Another study represents 92 tree species (37 familiy) recored from Chunati wildlife sanctuary (Rahman and Hossain 2003). Similarly, 62 naturally growing native tree species belonging to 30 families and 53 genera were found in Tankawati natural forest (Motaleb and Hossain 2011). The plant species composition of DDWS is higher in comparison to the tropical semi-evergreen forests of Manipur (123 species under 48 families) of North East India (Devi and Yadava 2006), though it is lower than Gandhamardan hill range (912 species, 556 genera and 142 families) of Orissa, India (Reddy and Pattanik 2009). Considering the results of these studies, it is obovious that the Dudhpukuria-Dhopachari Wildlife Sanctuary possesses comparatively diversified natural forest vegetation with maximum number of angiospermic plant species than that of many similar evergreen, deciduous and semi-deciduous forests of Bangladesh. Significant number of magnoliopsida (431 species), liliopsida (161 species) and pteridophytes (17 species) were recorded from the study area.

The presence of some exotic tree species, i.e., *Acacia* spp, *Swietenia mahagoni, Tectona grandis* is because of commercial plantations that were established in the area before it was declared as WS. Some homestead species, e.g., *Artocarpus heterophyllus, Psidium guajaba, Tamarindus indica, Senna siamia* etc. along with other shrubs and herbs occurred in the study area may be because of the dispersal of their seeds by various means like wind, surrounding people, animals etc.

A substantial number of people settled around the forest areas. Some plants of waste places, village thickets were found to grow within the forest area. As the original species composition of the undisturbed natural forest may not be restored once changed by human disturbance (Yadav and Gupta 2006), the situation demands urgent attention to enrich the plant diversity at general and species levels to avoid the risk of extinction of native species or genera with single species.

Conclusion

The present study provides a major enumeration of the floristic composition of this wildlife sanctuary. Presence of 609 plant species from different habit forms indicates the importance and potentiality of Dudhpukuria-Dhopachori WS for conservation of this natural ecosystem. The wildlife sanctuary is rich enough with floral diversity. The forest provides diverse products including timber, fuel wood, construction material, medicines, fodder, edible fruits and some non-timber forest products. Many local people living around the wildlife sanctuary area are solely dependent on the forests for their livelihood and daily essentials. The present study may serve as a primary database for future conservation and management of a number of native species essential for a protected area like Dudhpukuria-Dhopachori Wildlife Sanctuary.

Recommendations

Considering the findings of the present study, following recommendations are suggested in order to strengthen the conservation, management and sustainable utilization of the forest resources of Dudhpukuria-Dhopachori Wildlife Sanctuary.

- Forty two threatened plant species recorded from the wildlife sanctuary needs adequate conservation and better management option,
- Anthropogenic disturbances, e.g. bamboo extraction, illegal cutting, grazing, fire hazards and agricultural expansion (i.e. jhum, ginger, turmeric, paddy, tobacco, citrus cultivation etc.) in the forest areas must be controlled with the participation of the local stakeholders,
- Exotic species must not be used in the plantation activities,
- Native tree species, i.e. *Ficus* spp., *Artocarpus* spp., *Dipterocarpus* spp., *Syzygium* spp., *Protium serratum* etc. should be encouraged for enrichment plantation activities.

- The settlers living inside the forests need to be provided with alternative livelihood oppurtunities or rehabilitated outside the Wildlife Sanctuary.
- Co-management activities initiated by Forest Department, NGOs and Co-management Committee should be strengthened to ensure protection and conservation of the protected area.

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Appendix 1: List of plants recorded from Dudhpukuria-Dhopachori Wildlife Sanctuary

Botanical Name	Family	Local Name	Conservation status	Habit
Abrus precatorius L.	Fabaceae	Kuch	LC	C*
Abutilon persicum (Burm. F.) Merr.	Malvaceae		LC	H
Acacia auriculiformis A. Cunn. *ex* Benth. & Hook.	Mimosaceae	Akashmoni	LC	T
Acacia concinna (Willd.) DC.	Mimosaceae	Banrita, Kuchui	LC	C
Acacia mangium Willd.	Mimosaceae	Mangium	LC	T
Achyranthes aspera L.	Amaranthaceae	Apang, Upatlengra	LC	H
Acroceras zizanioides (H. B. K.) Dandy	Poaceae		LC	H
Acronychia pedunculata (L.) Miq.	Rutaceae	Jair-gola	NE	T
Actinodaphne angustifolia Ness.	Lauraceae	Modonmesta	NE	T
Actinoscirpus grossus (L.f.) Goetgh & D. A. Simpson	Cyperaceae	Kasuru, Kasari	LC	H
Adenia trilobata (Roxb.) Engl.	Passifloraceae	Akandaphal	LC	C
Adenostemma lavenia (L.) O. Kuntze	Asteraceae	Boro-kesuti	LC	H
Adiatum incisum Forssk.	Adiantaceae	Biddapata	NT	F
Adiatum latifolium Lam.	Adiantaceae	Biddapata	NT	F
Aegle marmelos (L.) Corrx	Rutaceae	Bel	LC	T
Aerides multiflora Roxb.	Orchidaceae		CD	E
Ageratum conyzoides L.	Asteraceae	Ochunti	LC	H
Aglaia chittagonga Miq.	Meliaceae	Thitpasing	CD	T
Aglaia perviridis Hiern	Meliaceae		NT	T
Aglaia spectabilis (Miq.) Jain & Bennet	Meliaceae	Lali, Rongi-rata	CD	T
Aidia micrantha (K. Schum.) Bullock *ex* F. White	Rubiaceae		CD	S
Aidia oppositifolia (Roxb.) Rahman & Das	Rubiaceae	Rapta Bhadi	CD	T
Alangium chinense (Lour.) Harms	Alangiaceae	Marleza Gachh	NER	T
Albizia chinensis (Osb.) Merr.	Mimosaceae	Chakua Koroi	LC	T
Albizia myriophylla (Roxb.) Benth.	Mimosaceae	Titulya Koroi	NER	S
Albizia odoratissima (L. f.) Benth.	Mimosaceae	Tetoya Koroi	LC	T

Botanical Name	Family	Local Name	Conservation status	Habit
Albizia procera (Roxb.) Benth.	Mimosaceae	Sada Koroi	LC	T
Allophylus cobbe (L.) Raeuschel var. *villosus* (Roxb.) Prain.	Sapindaceae	Chita, Rakhalchita	CD	S
Alocasia acuminata Schott	Araceae		V	H
Alpinia blepharocalyx K. Schum.	Zingiberaceae		LC	H
Alpinia conchigera Griff.	Zingiberaceae	Khetranga	LC	H
Alstonia scholaris (L.) R.Br.	Apocynaceae	Chatim	LC	T
Alternanthera philoxeroides (Mart.) Griseb.	Amaranthaceae	Helencha	LC	H
Amaranthus dubius Mart.	Amaranthaceae		LC	H
Amaranthus spinosus L.	Amaranthaceae	Kanta-nutia	LC	H
Amaranthus viridis L.	Amaranthaceae	Ban-nate, Notay	LC	H
Amischophacelus axillaris (L.) Rolla Rao & Kamm.	Commelinaceae	Baghanulla	LC	H
Amischotolype mollissima (Blume) Hassk. var. *glabrata* (Hassk.) Rolla Rao	Commelinaceae		NER	H
Amomum corynostachyum Wall.	Zingiberaceae	Tera	LC	H
Amorphophallus bulbifer (Roxb.) Blume	Araceae	Jongle Ol.	LC	H
Ampelocissus barbata (Wall.) Planch. in DC.	Vitaceae	Jarila-lahari	CD	C
Ampelocissus latifolia (Roxb.) Planch.	Vitaceae	Gowalia-lata	NE	C
Angiopteris evecta (Forst.) Hoffm	Angiopterida-ceae	Dhekia Shak	LC	F
Aniseia martinicensis (Jacq.) Choisy	Convolvulaceae		LC	C
Anisoptera scaphula (Roxb.) Pierre	Dipterocarpac-eae	Boilam	CD	T
Anogeissus acuminata (Roxb. *ex* DC.) Guill. & Perr.	Combretaceae	Seori, Chakwa	DD	T
Antidesma acidum Retz.	Euphorbiaceae	Multa	LC	S
Antidesma bunius (L.) Spreng.	Euphorbiaceae	Wishwar choa	LC	T
Antidesma roxburghii Wall. *ex* Tulasne	Euphorbiaceae		CD	S
Antidesma velutinum Tulasne	Euphorbiaceae	Pahari Elena	CD	T
Aphanamixis polystachya (Wall.) R.N. Parker	Meliaceae	Pitraj, Royna	LC	T
Aponogeton echinatus Roxb.	Aponogetona-ceae	Ghechu	CD	H

Botanical Name	Family	Local Name	Conservation status	Habit
Aponogeton natans (L.) Engl. & Krause	Aponogetona-ceae		NT	H
Aporosa aurea Hook. f.	Euphorbiaceae		NER	S
Aporosa wallichii Hook. f.	Euphorbiaceae	Kokra, Castoma	NE	T
Aquilaria agallocha Roxb.	Thymelaeaceae	Agar	LC	T
Ardisia humilis Thw.	Myrsinaceae	Chauldhoa	LC	S
Ardisia khasiana C. B. Clarke	Myrsinaceae		CD	S
Argyreia roxburghii Choisy	Convolvulaceae		NE	C
Aristolochia tagala Cham.	Aristolochia-ceae		LC	C
Artocarpus chama Buch.-Ham. *ex* Wall.	Moraceae	Chapalish	NER	T
Artocarpus heterophyllus Lamk.	Moraceae	Kanthal	LC	T
Artocarpus lacucha Buch-Ham.	Moraceae	Borta	LC	T
Asclepias curassavica L.	Asclepiadaceae	Moricha	LC	H
Atylosia scarabaeoides (L.) Baker	Fabaceae		E	C
Axonopus compressus (Sw.) P. Beauv.	Poaceae	Ghora dubo Har	LC	H
Baccaurea ramiflora Lour.	Euphorbiaceae	Lotkon	LC	T
Balanostreblus ilicifolius Kurz	Moraceae	Pahari Sheora	NER	S
Bambusa burmanica Gamble.	Poaceae	Mitinga Bans	NE	S
Bambusa tulda Roxb.	Poaceae	Mitinga, Mirtinga	LC	S
Bambusa vulgaris Schrad. *ex* Wendl.	Poaceae	Baijja, Baria	LC	S
Barleria strigosa Willd. var. *terminalis* (Nees) C.B. Clarke	Acanthaceae	Banmali	NER	S
Bauhinia scandens L.	Caesalpiniaceae	Nagpat, Gendi-lata	DD	C
Beaumontia grandiflora Wall.	Apocynaceae		NER	C
Berrya cordifolia (Willd.) Burrett.	Tiliaceae	Chavandalai	LC	T
Blechnum orientale L.	Blechnaceae		LC	F
Blumea balsamifera DC.	Asteraceae	Kakronda	NER	S
Blumea heiracifolia (D. Don) DC.	Asteraceae		LC	H
Blumea lacera (Burm. f.) DC.	Asteraceae	Barokukshim	LC	H
Blyxa echinosperma (C.B. Clarke) Hook.	Hydrocharitaceae		LC	H
Bombax insigne Wall.	Bombacaceae	Bon tula	NER	T
Bonamia semidigyna (Roxb.) Hallier f.	Convolvulaceae		NE	S

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Bothriochloa bladhii (Retz.) S. T. Blake	Poaceae	Gandha Gourana	LC	H
Brachiaria decumbens Stapf	Poaceae		LC	H
Brachiaria distachya (L.) Stapf	Poaceae	Cori Ghas	LC	H
Brassaiopsis glomerulata (Blume) Regel.	Araliaceae	Kurila	LC	T
Breynia retusa (Dennst.) Alston	Euphorbiaceae	Silpati	NE	S
Breynia vitis-idaea (Burn. f.) C. E. C. Fisher	Euphorbiaceae		NE	S
Bridelia retusa (L.) A. Juss.	Euphorbiaceae	Kata Koi	LC	T
Bridelia stipularis (L.) Blume	Euphorbiaceae		LC	S
Bridelia tomentosa Blume	Euphorbiaceae	Khoi	LC	S
Bridelia verrucosa Blume	Euphorbiaceae		NE	S
Brownlowia elata Roxb.	Tiliaceae	Moos, Mass	V	T
Buddleja asiatica Lour.	Buddljaceae	Neemda	LC	S
Bulbophyllum lobbii Lindl.	Orchidaceae		NT	E
Butea monosperma (Lam.) Taub.	Fabaceae	Palash	LC	T
Byttneria pilosa Roxb.	Sterculiaceae	Harbanga lata	NE	C
Caesalpinia bonduc (L) Roxb.	Caesalpiniaceae	Nata, Lal kanta	LC	C
Caesalpinia digyna Rottler	Caesalpiniaceae	Kochoi	LC	S
Caesalpinia hymenocarpa (Prain) Hattink.	Caesalpiniaceae		NER	S
Caesalpinia pulcherrima (L.) Swartz.	Caesalpiniaceae	Radhachura	LC	T
Caesalpinia sappan L.	Caesalpiniaceae	Bakam, Petang	NER	S
Calamus guruba Buch.-Ham. *ex* Martius	Arecaceae	Jali Bet, Kejuni Bet	V	C
Calamus latifolius Roxb.	Arecaceae	Budum bet	V	C
Calamus tenuis Roxb.	Arecaceae	Sanchi Bet	LC	C
Calamus viminalis Willd.	Arecaceae	Khorkhoijja Bet	LC	C
Callicarpa arborea Roxb.	Verbenaceae	Bormala, Khoja	LC	T
Calophyllum polyanthum Wall. *ex* Choisy	Clusiaceae	Chandua, Kamdeb	NER	T
Calycopteris floribunda (Roxb.) Lamk.	Combretaceae	guicha Lata	LC	S
Campanumoea javanica Blume	Campanulaceae	Gede	V	H
Campanumoea lancifolia (Roxb.) Merr.	Campanulaceae		LC	H

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Canthium horridum Blume	Rubiaceae	Bismon kanta	CD	T
Canthium parvifolium Roxb.	Rubiaceae	Bish-main	V	S
Capillipedium assimile (Steud.) A Camus	Poaceae		DD	H
Capparis zeylanica L.	Capparaceae		LC	S
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	Roscao	LC	T
Cardiospermum halicacabum L.	Sapindaceae	Phutka, Lataphutki	LC	C
Carex indica L.	Cyperaceae		LC	H
Caryota mitis Lour.	Arecaceae		V	T
Caryota urens L.	Arecaceae	Chau, Sago Palm	LC	T
Cassia fistula L.	Caesalpiniaceae	Sonalu	LC	T
Cassia nodosa Buch-Hum. *ex* Roxb.	Caesalpiniaceae	Bon-sonalu	LC	T
Cayratia japonica (Thunb.) Gagnep.	Vitaceae		LC	C
Celastrus paniculatus Willd.	Celastraceae	Malkangni	NT	S
Celosia cristata L.	Amaranthaceae	Morogphul	LC	H
Centella asiatica (L.) Urban	Apiaceae	Thankuni	LC	H
Ceriscoides campanulata (Roxb.) Tirveng.	Rubiaceae	Boilem	V	T
Cheilanthes farinosa (Forsk) Kaulf.	Sinopteridaceae	Shada Dhekia	LC	F
Chionachne koenigii (Spreng.) Thw.	Poaceae	Gurgur	NE	H
Chisocheton cumingianus (C. DC.)	Meliaceae	Kalikora, Rata	LC	T
Chromolaena odorata (L.) King & Robinson	Asteraceae	Assamlata	LC	H
Chrysopogon aciculatus (Retz.) Trin.	Poaceae	Lengra, Premkanta	LC	H
Chukrasia tabularis A. Juss.	Meliaceae	Chickrassi	LC	T
Cinnamomum iners Reinw. *ex* Blume.	Lauraceae	Tez-bohu	CD	T
Cissus adnata Roxb.	Vitaceae	Painna lata	LC	C
Cissus repens Lamk.	Vitaceae	Marmaria-pata	DD	C
Citrus aurantifolia (Christ. & Panzer) Swingle	Rutaceae	Lebu	LC	S
Clausena heptaphylla (Roxb.) Wight & Arn. *ex* Steud.	Rutaceae	Karan phal, Panbahar	LC	S
Clausena suffruticosa (Roxb.) Wight & Arn.	Rutaceae	Kalomoricha	LC	S
Clematis cadmia Buch.-Ham. *ex* Hook. f. & Thoms.	Ranunculaceae	Bon-marich	LC	C

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Cleome rutidosperma DC.	Capparaceae	Bathoishakh	LC	H
Clerodendrum viscosum Vent.	Verbenaceae	Bhant, Ghetuphul	LC	S
Clerodendrum wallichii Merr.	Verbenaceae	Dieng-julkah	NER	S
Coccinia grandis (L.) Voigt.	Cucurbitaceae	Telakucha	LC	C
Cocos nucifera L.	Arecaceae	Narikel	LC	T
Colocasia esculenta (L.) Schott	Araceae	Katchu	LC	H
Colocasia fallax Schott.	Araceae		LC	H
Colocasia oresbia A. Hay	Araceae	Sadakachu	V	H
Combretum decandrum Roxb.	Combretaceae	Kali goicha	LC	C
Combretum punctatum Blume subsp. *squamosum* (Roxb. *ex* G. Don) Excell	Combretaceae		NE	S
Commelina benghalensis L.	Commelinaceae	Dholpata, Kanchira	LC	H
Commelina longifolia Lamk.	Commelinaceae	Pani kanchira	LC	H
Commelina paludosa Blume	Commelinaceae	Jata Kanchira	LC	H
Commelina sikkimensis C.B. Clarke	Commelinaceae	Batbaithia Shag	CD	H
Connarus paniculatus Roxb.	Connaraceae	Katgular	LC	C
Conyza aegyptiaca (L.) W. Ait.	Asteraceae		NER	H
Conyza leucantha (D. Don) Lud. & Rav.	Asteraceae		NE	H
Cosmostigma racemosa (Roxb.) Wight & Arn.	Asclepiadaceae		NER	S
Costus speciosus (Koenig *ex* Retz) Smith	Costaceae	Bonroi, Khustha	LC	H
Crotalaria acicularis Buch.-Ham. *ex* Benth. & Hook	Fabaceae		LC	H
Crotalaria anagyroides H.B. & K.	Fabaceae		LC	S
Crotalaria pallida Ait.	Fabaceae	Jan-jhani	LC	S
Crotalaria spectabilis Roth	Fabaceae	Pipli-jhunjan	LC	S
Croton roxburghii Balakr.	Euphorbiaceae	Baragachh, Chuka	NE	S
Crypteronia paniculata Blume.	Crypteroniaceae	Goru-mara	NER	T
Cryptocarya amygdalina Nees.	Lauraceae	Bhuiya Gachh	NER	T
Curculigo latifolia (Dryand.) Ait.	Liliaceae		LC	H
Curcuma zedoaria (Christm.) Rosc.	Zingiberaceae	Shoti, Failla	LC	H
Cuscuta chittagongensis Sen Gupta	Cuscutaceae	Pahari Swarnalata	LC	P

Botanical Name	Family	Local Name	Conservation status	Habit
Cuscuta reflexa Roxb.	Cuscutaceae	Swarnalata	LC	P
Cyanotis cristata (L.) D. Don	Commelinaceae		LC	H
Cyathula prostrata (L.) Blume.	Amaranthaceae		Rare	H
Cyclea barbata Miers.	Menispermaceae	Patalpur	NT	C
Cymbopogon citratus (DC.) Stapf	Poaceae	Lemon Ghas	CD	H
Cymbopogon nardus (L.) Rendle in Hiern.	Poaceae	Gandha Bena	CD	H
Cynodon arcuatus J. S. Presl *ex* C. B. Presl	Poaceae		LC	H
Cynodon dactylon (L.) Pers.	Poaceae	Durba grass	LC	H
Cyperus compressus L.	Cyperaceae	Chanch	LC	H
Cyperus corymbosus Rottb.	Cyperaceae	Gola Methi	NE	H
Cyperus cyperoides (L.) O. Ktze.	Cyperaceae	Kucha, Kusha	LC	H
Cyperus difformis L.	Cyperaceae	Behua	LC	H
Cyperus digitatus Roxb.	Cyperaceae	Behua	LC	H
Cyperus distans L. f.	Cyperaceae	Pani Malanga	LC	H
Cyperus exaltatus Retz.	Cyperaceae		LC	H
Cyperus iria L.	Cyperaceae	Barachucha	LC	H
Cyperus laxus Lamk var. laxus	Cyperaceae		LC	H
Cyperus nutans Vahl	Cyperaceae		LC	H
Cyperus odoratus L.	Cyperaceae		NE	H
Cyperus rotundus L.	Cyperaceae	Mutha	LC	H
Cyperus tenuiculmis Boeck.	Cyperaceae		NE	H
Cyperus tenuispica Steud.	Cyperaceae		LC	H
Cyperus tuberosus Rottb.	Cyperaceae		LC	H
Cyrtococcum accrescens (Trin.) Stapf	Poaceae		LC	H
Cyrtococcum oxyphyllum (Steud.) Stapf	Poaceae		LC	H
Cyrtococcum patens (L.) A. Camus	Poaceae		LC	H
Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae	Makra	LC	H
Daemonorops jenkinsiana (Griff.) Martius	Arecaceae	Golla, Golak Bet	LC	C
Dalbergia pinnata (Lour.) Prain	Fabaceae	Lalong-chhali, Keti	LC	C
Dalbergia spinosa Roxb.	Fabaceae	Chulia-kanta	LC	S
Dalbergia stipulacea Roxb.	Fabaceae	Dadbari	LC	C
Dalbergia tamarindifolia Roxb.	Fabaceae	Keti	CD	S
Deeringia amaranthoides (Lamk.) Merr.	Amaranthaceae	Gholemouni	LC	S
Dendrobium fimbriatum Hook. f.	Orchidaceae		V	E
Dendrocalamus longispathus (Kurz) Kurz	Poaceae	Ora	NE	S

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Dendrolobium triangulare (Retz.) Merr.	Fabaceae	Bir Jarwar	LC	S
Derris elliptica (Wall.) Benth.	Fabaceae		CD	S
Derris marginata (Roxb.) Benth.	Fabaceae	Makrigila	LC	C
Derris robusta (Roxb. *ex* DC.) Benth.	Fabaceae	Jangaria, Jhamurja	LC	T
Desmodium heterocarpon (L.) DC.	Fabaceae		CD	S
Desmodium heterophyllum (Willd.) DC.	Fabaceae		LC	H
Desmodium pulchellum (L.) Benth.	Fabaceae	Juta-salpani	LC	S
Desmodium triquetrum (L.) DC.	Fabaceae		DD	S
Desmodium triquetrum (L.) DC. subsp. *pseudo-triquetrum* (DC) Prain	Fabaceae		NE	S
Desmos chinensis Lour.	Annonaceae	Joke lata	DD	S
Dichanthium caricosum (L.) A. Camus	Poaceae	Detara	LC	H
Dicranopteris linearis (Burm. f.) Underw.	Gleicheniaceae	Lomba, Dhekia	LC	F
Didymosperma gracilis Hook. f.	Arecaceae	Bon Supari	CD	T
Dillenia indica L.	Dilleniaceae	Chalta	LC	T
Dillenia scabrella Roxb. *ex* Wall.	Dilleniaceae	Hargeza	LC	T
Dioscorea aculeata L.	Dioscoreaceae	Jointa Alu	LC	C
Dioscorea belophylla (Prain) Voigt *ex* Haines	Dioscoreaceae	Shora Alu	LC	C
Dioscorea bulbefera L.	Dioscoreaceae	Pagla Alu	LC	C
Dioscorea hamiltonii Hook. f.	Dioscoreaceae	Thakan Budo	NT	C
Dioscorea pentaphylla L.	Dioscoreaceae	Alu lata	LC	C
Dioscorea tomentosa Koen. ex Spreng.	Dioscoreaceae		LC	C
Diospyros malabarica (Desr.) Kostel.	Ebenaceae	Deshi gab	LC	T
Diospyros toposia Buch.-Ham.	Ebenaceae	Katgula, Toposi	LC	T
Diplazium esculentum (Retz.) Sw.	Athyriaceae	Dhekia	LC	F
Diplazium polypodioides Bl.	Athyriaceae	Dhekia	V	F
Dipterocarpus alatus Roxb. *ex* G. Don	Dipterocarpaceae	Gorjon (Sada)	LC	T
Dipterocarpus costatus Gaertn.	Dipterocarpaceae	Baitta gorjon	CD	T
Dipterocarpus turbinatus Gaertn.	Dipterocarpaceae	Tellia gorjon	LC	T
Dischidia major (Vahl) Merr.	Asclepiadaceae		NER	E

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Discospermum abnorme (Korth.) Ali & Robbr.	Rubiaceae		V	T
Drimycarpus racemosus Hook. f.	Anacardiaceae	Nala-amshi	NER	T
Drynaria quercifolia (L.) J. Sm.	Polypodiaceae	Chotto Pankhiraj	LC	F
Duabanga grandiflora (Roxb. *ex* DC.) Walp.	Sonneratiaceae	Bandarhola	LC	T
Dysoxylum binectariferum (Roxb.) Hook. f. *ex* Beddome	Meliaceae	Rangirata, Rata	CD	T
Dysoxylum excelsum Blume	Meliaceae	Koirga Pitraz	LC	T
Echinochloa crusgalli (L.) P. Beauv.	Poaceae	Bara Shama-ghas	LC	H
Eclipta alba (L.) Hassk.	Asteraceae	Kesaraj, Bhimraj	LC	H
Ehretia serrata Roxb.	Boraginaceae	Kala-huja	LC	T
Elaeagnus latifolia L.	Elaeagnaceae	Bon-Jara, Guara	NER	S
Elaeocarpus floribundus Blume.	Elaeocarpaceae	Sada Jalpai, Belpoi	LC	T
Elaeocarpus tectorius (Lour.) Poir.	Elaeocarpaceae	Jolpai	LC	T
Elaeocarpus varunua Buch.-Hum *ex* Masters	Elaeocarpaceae	Bon Jalpai, Titpai	CD	T
Eleocharis acutangula (Roxb.) Schult.	Cyperaceae		LC	H
Eleocharis congesta D. Don	Cyperaceae		LC	H
Eleocharis retroflexa (Poir.) Urban. Subsp. *chetaria* (Roem. & Schult.) T. Koyama	Cyperaceae		LC	H
Elephantopus scaber L.	Asteraceae		LC	H
Eleusine indica (L.) Gaertn.	Poaceae	Malankuri	LC	H
Embelia ribes Burm. f.	Myrsinaceae	Kumiazzalata	CD	C
Engelhardtia spicata Lesch. *ex* Blume.	Juglandaceae	Jhumka bhadi	NE	T
Entada rheedii Spreng.	Mimosaceae	Gilalata	NER	C
Eragrostis gangetica (Roxb.) Steud.	Poaceae		LC	H
Eragrostis lehmanniana Nees	Poaceae		NE	H
Eragrostis tenella (L.) P. Beauv. *ex* Roem. & Schult.	Poaceae	Koni Ghas	LC	H
Erianthus longisetosus Anders.	Poaceae		NT	H
Eriophorum comosum (Wall.) Wall. *ex* Nees	Cyperaceae		NT	H

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Erythrina fusca Lour.	Fabaceae	Panya Mandar	LC	T
Erythropalum scandens Blume	Olacaceae	Not Known	LC	S
Etlingera linguiformis (Roxb.) R.M. Smith	Zingiberaceae		LC	H
Euphorbia heterophylla L.	Euphorbiaceae		NER	H
Euphorbia hirta L.	Euphorbiaceae	Dhudhiya	LC	H
Euphorbia serpens H.B. & K.	Euphorbiaceae		LC	H
Euphorbia thymifolia L.	Euphorbiaceae	Dudhiya, Swetkan	LC	H
Eurya acuminata DC.	Theaceae	Sagoler bori, Lapet	CD	S
Fagerlindia fasciculata (Roxb.) Tirveng.	Rubiaceae		V	S
Ficus auriculata Lour.	Moraceae	Baradumur, Battomeza	LC	T
Ficus benghalensis L.	Moraceae	Bot	LC	T
Ficus fistulosa Reinw. *Ex* Blume.	Moraceae		NE	T
Ficus hispida L. f.	Moraceae	Dumur	LC	T
Ficus lamponga Miq.	Moraceae	Jig bot, Katgularia	LC	T
Ficus nervosa Heyne *ex* Roth	Moraceae	Panidumur	LC	T
Ficus racemosa L.	Moraceae	Jagyadumur	LC	T
Ficus semicordata Buch.-Ham. *ex* Smith	Moraceae	Chokorgola	NE	T
Ficus variegata Blume.	Moraceae		NE	T
Fimbristylis alboviridis C.B. Clarke	Cyperaceae		LC	H
Fimbristylis dichotoma (L.) Vahl.	Cyperaceae	Bara Nirbishi	LC	H
Fimbristylis miliacea (L.) Vahl.	Cyperaceae	Bara Javani	LC	H
Flacourtia jangomas (Lour.) Raeusch.	Flacourtiaceae	Painnagola	LC	T
Flemingia macrophylla (Willd.) O. Kuntze *ex* Merr.	Fabaceae	Bara Salphan	LC	C
Flemingia strobilifera (L.) R. Br.	Fabaceae	Sim Busak	LC	S
Fuirena ciliaris (L.) Roxb.	Cyperaceae		LC	H
Fuirena umbellata Rottb.	Cyperaceae		LC	H
Garcinia cowa Roxb. *ex.* DC.	Clusiaceae	Kao	LC	T
Garcinia morella (Gaertn.) Desr.	Clusiaceae	Moigga Kao	DD	T
Garcinia xanthochymus Hook. f. *ex* T. Anders.	Clusiaceae	Tamal, Dephal	LC	T
Gardenia coronaria Buch.-Ham.	Rubiaceae	Bankamal	V	T

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Garuga pinnata Roxb.	Burseraceae	Bhadi, Silbhadi	LC	T
Genianthus laurifolius (Roxb.) Hook. f.	Asclepiadaceae		NER	S
Gigantochloa andamanica (Kurz) Kurz.	Poaceae	Kaliseri, Kalia, Kalibans	NE	S
Globba multiflora Wall. *ex* Baker	Zingiberaceae		NER	H
Glochidion lanceolarium (Roxb.) Voigt.	Euphorbiaceae	Anguti, Bhauri	LC	T
Glochidion multiloculare (Roxb. *ex* Willd.) Muell.- Arg.	Euphorbiaceae	Paniatori	LC	T
Glochidion velutinum Wight	Euphorbiaceae	Painnatora	LC	T
Gluta elegans (Wall.) Hook. f.	Anacardiaceae	Kabita	NE	T
Glycosmis pentaphylla (Retz.) A. DC.	Rutaceae	Bonjamir, Jair gola	LC	T
Gmelina arborea Roxb.	Verbenaceae	Gamar	LC	T
Grevillea robusta A. Cunn. *ex* R. Br.	Proteaceae	Fern Tree	NT	T
Grewia asiatica L.	Tiliaceae	Pholsa	NER	S
Grewia lancaefolia Roxb.	Tiliaceae		NE	S
Grewia nervosa (Lour.) Panigr.	Tiliaceae	Assar	LC	T
Grewia serrulata DC.	Tiliaceae	Panisara, Pichandi	LC	S
Grewia tiliifolia Vahl.	Tiliaceae	Pholsa, Dhomoni	LC	T
Gymnema acuminatum (Roxb.) Wall.	Asclepiadaceae	Khara Lata	NER	S
Haldina cordifolia (Roxb.) Ridsdale.	Rubiaceae	Haldu, Dakrum	CD	T
Harpullia cupanoides Roxb.	Sapindaceae	Harpuli, Juribisi	NT	T
Hedyotis hermaniana Dutta	Rubiaceae		NE	H
Hedyotis scandens Roxb.	Rubiaceae	Bish Lata, Latamel	LC	H
Heliotropium indicum L.	Boraginaceae	Hatisur	LC	H
Helixanthera parasitica Lour.	Loranthaceae		DD	P
Helminthostachys zeylanica (L.) Hook.	Helminthostachyceae	Shada Dhekia	LC	F
Hewittia sublobata (L. f.) O. Kuntze	Convolvulaceae		LC	C
Hibiscus aculeatus Roxb.	Malvaceae	Chukhal	LC	S
Hibiscus scandens Roxb.	Malvaceae		CD	C
Hibiscus surattensis L.	Malvaceae		LC	H

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Himalrandia tetrasperma (Roxb.) T.	Rubiaceae		CD	S
Holarrhena antidysenterica (L.) Wall.*ex* Decne	Apocynaceae	Kurchi, Kuruj	LC	T
Homalomena aromatica (Roxb. *ex* Sim) Schott	Araceae		V	H
Homalomena coerulescens Jungh.	Araceae		V	H
Hopea odorata Roxb.	Dipterocarpaceae	Telsur	LC	T
Hoya parasitica (Roxb.) Wall. *ex* Wight	Asclepiadaceae	Pargacha	LC	P
Hydnocarpus laurifolius (Dennst.) Sleum.	Flacourtiaceae	Hiddigach	NER	T
Hygrophila polysperma (Roxb.) T. Anders.	Acanthaceae		LC	H
Hypolytrum nemorum (Vahl.) Spreng.	Cyperaceae		LC	H
Hyptis suaveolens (L.) Poit.	Lamiaceae	Tokma	LC	H
Ichnocarpus frutescens (L.) R. Br.	Apocynaceae	Dudhi Lata	LC	S
Ilex godajam Colebr. *ex* Hook. f.	Aquifoliaceae	Jangligewa	LC	T
Imperata cylindrica (L.) Beauv. Var. *latifolia* (Hook.f.) C.E. Hubb.	Poaceae	Chhan, Chau, Kash	LC	H
Imperata cylindrica (L.) P. Beauv. var. *major* (Nees) C.E. Hubb. & Vaughan	Poaceae	Sungrass	LC	H
Indigofera suffruticosa Mill.	Fabaceae	Belati Nil	NE	S
Ipomoea fistulosa Mart. *ex* Choisy	Convolvulaceae	Kolmi, Dhol Kolmi	LC	S
Ipomoea hederifolia L.	Convolvulaceae		LC	C
Ipomoea maxima (L. f.) D. Don *ex* Sweet	Convolvulaceae	Ban Kalmi	LC	C'
Ipomoea pes-tigridis L.	Convolvulaceae	Langulilata	LC	C
Ipomoea yomae Kurz	Convolvulaceae		DD	C
Isachne pulchella Roth *ex* Roem. & Schult.	Poaceae		NER	H
Ischaemum thomsonianum Stapf *ex* C. E. C. Fischer	Poaceae		NE	H
Ixora acuminata Roxb.	Rubiaceae		CD	S
Ixora cuneifolia Roxb.	Rubiaceae	Beophul	V	S
Jasminum multiflorum (Burm. F.) Andr.	Oleaceae	Kund,Chameli	LC	S
Jasminum sambac (L.) Ait.	Oleaceae	Beli	LC	S
Jasminum scandens Vahl.	Oleaceae	Not Known	NE	C
Juncus prismatocarpus R.Br.	Juncaceae		LC	H
Justicia diffusa Willd.	Acanthaceae	Pitapapra	NE	H

Botanical Name	Family	Local Name	Conservation status	Habit
Kyllinga brevifolia Rottb.	Cyperaceae		LC	H
Kyllinga bulbosa Beauv.	Cyperaceae		LC	H
Kyllinga nemoralis (J.R. Forst. & G. Forst.) Dandy ex Hutchins. & Dalziel	Cyperaceae		LC	H
Lagerstroemia indica L.	Lythraceae	Goicha Jarul	LC	S
Lagerstroemia macrocarpa Wall.	Lythraceae	Bansua Jarul	DD	T
Lagerstroemia speciosa (L.) Pers.	Lythraceae	Painna Jarul	LC	T
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	Jial Bhadi	LC	T
Lantana camara L. var. *aculeata* (L.) Moldenke & Moldenke	Verbenaceae	Lantana	LC	S
Lasianthus hirsutus (Roxb.) Merr.	Rubiaceae	Kala Long	V	S
Leea aequata L.	Leeaceae		LC	S
Leea indica Merr.	Leeaceae	Kurkur Jihwa	LC	S
Leea robusta Roxb.	Leeaceae		NE	T
Lemna perpusilla Torrey	Lemnaceae		LC	H
Lepidagathis incurva Buch.-Ham. *ex* P. Don.	Acanthaceae		LC	S
Lepisanthes rubiginosa (Roxb.) Leenh.	Sapindaceae	Baraharina	LC	T
Lepisanthes senegalensis (Poir.) Leenth.	Sapindaceae	Gotaharina	LC	S
Leucas aspera (Willd.) Link.	Lamiaceae	Shetodrona	LC	H
Leucas biflora (Vahl.) Benth.	Lamiaceae		V	H
Leucas indica (L.) R.Br. *ex* Vatke	Lamiaceae	Dandakolas, Haldusha, Sweetadrone	LC	H
Licuala peltata Roxb.	Arecaceae	Chhata Pat, Kurud	V	T
Lindernia procumbens (Krocker) Philcox	Scrophularia-ceae	Bakpuspa	LC	H
Lindernia viscosa (Hornemann) Boldingh	Scrophularia-ceae		LC	H
Lindsaea ensifolia Sw.	Lindsaeaceae	Bon Dhekia	LC	F
Lithocarpus acuminata (Roxb.) Rehder	Fagaceae	Kali Batna	E	T
Lithocarpus elegans var. *elegans* (Blume) Hatus. *ex* Soepad.	Fagaceae	Tal batna, Ramkota	NE	T
Lithocarpus pachyphylla (Kurz) Rehder	Fagaceae	Kanta Batna	NE	T
Lithocarpus polystachya (Wall. *ex* A. DC.) Rehder	Fagaceae	Sada Batna	NT	T

Botanical Name	Family	Local Name	Conservation status	Habit
Litsea glutinosa (Lour.) Robinson.	Lauraceae	Karjuki menda	LC	T
Litsea salicifolia (Roxb. *ex* Nees) Hook. f.	Lauraceae	Sum, Digloti	NE	S
Lygodium circinatum (Burm.f.) Sw.	Lygodiaceae	Lata Dhekia	NT	F
Lygodium flexuosum (L.) Sw.	Lygodiaceae	Lata Dhekia	LC	F
Macaranga denticulata (Blume) Muell.-Arg.	Euphorbiaceae	Bura	LC	T
Macaranga indica Wight	Euphorbiaceae		V	T
Macaranga peltata (Roxb.) Muell.-Arg.	Euphorbiaceae	Nonya Kotchi	LC	T
Maclura cochinchinensis (Lour.) Corner	Moraceae		LC	S
Maclura fruticosa (Roxb.) Corner	Moraceae		NER	S
Macrosolen cochinchinensis (Lour.) Van Tiegh.	Loranthaceae	Choto Banda	LC	P
Maesa chisia F. Ham. *ex* D. Don.	Myrsinaceae	Gangu-loda	CD	T
Maesa indica (Roxb.) A.DC.	Myrsinaceae	Romjani	CD	T
Maesa ramentacea (Roxb.) A.DC.	Myrsinaceae	Lal Moricha	LC	S
Mallotus philippensis (Lamk.) Muell.-Arg.	Euphorbiaceae	Sinduri	CD	S
Mallotus roxburghianus Muell.-Arg.	Euphorbiaceae	Nuniakachi, Gulli	NE	S
Mallotus tetracoccus (Roxb.) Kurz.	Euphorbiaceae	Kumaribura	LC	T
Mangifera indica L.	Anacardiaceae	Am	LC	T
Mangifera sylvatica Roxb.	Anacardiaceae	Uri-Am	V	T
Mapania palustris (Hassk. *ex* Steud.) Fern.-Vill.	Cyperaceae		NT	H
Maranta arundinacea L.	Marantaceae	Tukhur, Tukhur Aararut	NE	H
Melastoma malabathricum L.	Melastomataceae	Bontezpata	LC	S
Melocanna baccifera (Roxb.) Kurz	Poaceae	Muli	LC	S
Merremia hederacea (Burm. f.) Hallier f.	Convolvulaceae	Kaladana	LC	C
Merremia hirta (L.) Merr.	Convolvulaceae		LC	C
Merremia tridentata (L.) Hallier f.	Convolvulaceae		NER	C
Merremia umbellata (L.) Hallier f.	Convolvulaceae	Sada Kalmi	LC	C
Merremia vitifolia (Burm. f.) Hallier f.	Convolvulaceae		LC	C
Michelia baillonii (Pierre) Finet & Gagnep	Magnoliaceae	Bol-miring	NE	T

Botanical Name	Family	Local Name	Conservation status	Habit
Micromelum minutum (J.G. Forster) Wight & Arn.	Rutaceae	Dulia	NER	T
Microsorum punctatum (L.) Copel.	Polypodiaceae	Gucha patra	LC	F
Mikania cordata (Burm. f.) Robinson	Asteraceae	Assam lata	LC	C
Mimosa pudica L.	Mimosaceae	Lajjabati, Sarminda	LC	H
Mitracarpus hirtus (L.) DC.	Rubiaceae		LC	H
Mitragyna diversifolia (Wall. *ex* G. Don) Havil	Rubiaceae	Phul Kadom	CD	T
Mitragyna parvifolia (Roxb.) korth. Var. *microphylla* (Kurz) Ridsdale	Rubiaceae	Tobba, Phuti Kadom	CD	T
Mitragyna rotundifolia (Roxb.) O. Kuntze	Rubiaceae	Dakurum	NT	T
Molineria recurvata (Dryand.) Herbert.	Liliaceae	Satipata	LC	H
Monochoria hastata (L.) Solms.	Pontederiaceae	Baranukha	LC	H
Monochoria vaginalis (Burm. f.) Presl.	Pontederiaceae	Nukha, Sarkachu	LC	H
Morinda angustifolia Roxb.	Rubiaceae	Bonmali	LC	S
Morinda citrifolia L.	Rubiaceae		LC	S
Mucuna bracteata DC. *ex* Kurz	Fabaceae	Wakmi	V	C
Musa ornata Roxb.	Musaceae	Kola	CD	H
Mussaenda roxburghii Hook. f.	Rubiaceae	Chauri-Chaonri	NE	S
Mycetia longifolia (Wall.) O. Kuntze	Rubiaceae		CD	S
Myristica linifolia Roxb.	Myristacaceae	Am Barela	LC	T
Myxopyrum smilacifolium (Wall.) Blume	Oleaceae	Not Known	NT	S
Naravelia zeylanica (L.) DC.	Ranunculaceae	Chagul Bati	LC	C
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Kadam	LC	T
Neonauclea sessilifolia (Roxb.) Merr.	Rubiaceae	Kom	CD	T
Ochna pumila Buch.-Ham. *ex* DC.	Ochnaceae	Bhui Champa	NER	S
Olax imbricata Roxb.	Olacaceae	Not Known	NER	S
Operculina turpethum (L.) S. Manso	Convolvulaceae	Dudh Kalmi	LC	C
Ophiorrhiza mungos L.	Rubiaceae	Gandhanakuli	V	H

Botanical Name	Family	Local Name	Conservation status	Habit
Oplismenus burmanii (Retz.) P. Beauv.	Poaceae		LC	H
Oplismenus compositus (L.) P. Beauv.	Poaceae		LC	H
Ormosia robusta (Roxb.) Baker	Fabaceae		DD	T
Oroxylum indicum (L.) Kurz	Bignoniaceae	Khona, Kanaidingi	LC	T
Osbeckia truncata D.Don. *ex* Wight & Arn.	Melastomataceae		NER	H
Paederia cruddasiana Prain	Rubiaceae	Gandha-bhadali	CD	C
Paederia lanuginosa Wall.	Rubiaceae		CD	C
Pajanelia longifolia (Willd.) K. Schum.	Bignoniaceae	Monkhana	LR	T
Palaquium polyanthum Engl.	Sapotaceae	Tali	NE	T
Pandanus minor Buch.-Ham *ex* Wall.	Pandanaceae	Choto Keya	NE	S
Panicum brevifolium L.	Poaceae		LC	H
Panicum paludosum Roxb.	Poaceae	Barti, Borali	LC	H
Parthenocissus himalayana (Royle) Planch.	Vitaceae		NER	C
Paspalidium flavidum (Retz.) A. Camus	Poaceae	Bolai Mandi	LC	H
Paspalidium punctatum (Burm.) A. Camus	Poaceae	Petinar	LC	H
Paspalum conjugatum Bergius	Poaceae		LC	H
Paspalum longifolium Roxb.	Poaceae		NE	H
Paspalum orbiculare G. Forst.	Poaceae		LC	H
Pavetta indica L.	Rubiaceae	Bana Mali, Bisophal	LC	S
Peliosanthes teta Andr.	Haemodoraceae	Napigach	NE	H
Peristylus constrictus (Lindl.) Lindl.	Orchidaceae	Bhuinora	LC	H
Persea bombycina (King *ex* Hook. f.) Kosterm.	Lauraceae	Nalaomshi, Sada modonmossol	NE	T
Persicaria glabra (Willd.) Gomez de la Maza	Polygonaceae	Lal-kukri, Bihogni	LC	H
Phoebe lanceolata (Ness) Ness	Lauraceae	Chaongri, Dulia	NE	T
Phoenix sylvestris Roxb.	Arecaceae	Khejur	LC	T

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Phragmites karka (Retz.) Trin. *ex* Steud.	Poaceae	Dharma, Nalkhagra	LC	H
Phrynium imbricatum Roxb.	Marantaceae	Pituli Pata	NE	H
Phyla nodiflora (L.) Greene	Verbenaceae	Bhuiokra	LC	H
Phyllanthus emblica L.	Euphorbiaceae	Amloki	LC	T
Phyllanthus niruri L.	Euphorbiaceae	Bhuiamala	LC	H
Phyllanthus reticulatus Poir.	Euphorbiaceae	Chiki, Pankushi	LC	T
Phyllanthus sikkimensis Muell.-Arg.	Euphorbiaceae		NE	S
Phyllanthus urinaria L.	Euphorbiaceae	Hazarmani	LC	H
Physalis angulata L.	Solanaceae	Fotka	LC	H
Picrasma javanica Blume.	Simaroubaceae	Banposhla, Nilghanta	NER	T
Pilea melastomoides (Poir.) Wedd.	Urticaceae		E	S
Piper hamiltonii C. DC.	Piperaceae	Jangali Pan	V	C
Piper peepuloides Roxb.	Piperaceae	Pipal	LC	C
Pistia stratiotes L.	Araceae	Topapana	LC	H
Pithecellobium angulatum Benth.	Mimosaceae	Jigra, Kurmar, Morogmara	NE	T
Plumbago indica L.	Plumbaginaceae	Raktachita	CD	H
Pogonatherum paniceum (Lamk.) Hack.	Poaceae		NE	H
Pogostemon auricularius (L.) Hassk.	Lamiaceae	Bara-silenta	LC	H
Pollia secundiflora (Blume) Bakh. f.	Commelinaceae		NT	H
Polygala furcata Royle	Polygalaceae		V	H
Pothos scandens L.	Araceae	Hatilata, Batilata	V	E
Premna coriacea C.B. Clarke	Verbenaceae		V	S
Premna esculenta Roxb.	Verbenaceae	Lalana	LC	S
Protium serratum (Wall. *ex* Coelbr.) Engl.	Burseraceae	Gotgutia	LC	T
Psidium guajaba L.	Myrtaceae	Payara	LC	T
Psychotria adenophylla Wall.	Rubiaceae	Baro Sudma	CD	S
Psychotria monticola Kurz	Rubiaceae	Hatichotra	CD	S
Psychotria symplocifolia Kurz	Rubiaceae		V	S
Pteris geminata Wall.	Pteridaceae	Dhekia	CD	F
Pteris pseudopellucida Ching.	Pteridaceae	Dhekia.	DD	F
Pterospermum acerifolium (L.) Willd.	Sterculiaceae	Muskanda	LC	T

Botanical Name	Family	Local Name	Conservation status	Habit
Pterospermum semisagittatum Buch.-Ham. *ex* Roxb.	Sterculiaceae	Lana-assar	LC	T
Pueraria peduncularis (Grah. *ex* Benth.) Benth.	Fabaceae		LC	H
Pycreus pumilus (L.) Ness *ex* C. B. C. Clarke	Cyperaceae		LC	H
Raphistemma pulchellum (Roxb.) Wall.	Asclepiadaceae		NER	S
Rauvolfia serpentina (L.) Benth. *ex* Kurz.	Apocynaceae	Sarpagandha	CD	H
Rhaphidophora hongkongensis Schott	Araceae		V	H
Rhynchodia wallichii Benth.	Apocynaceae		NER	S
Rhynchospora corymbosa (L.) Britton	Cyperaceae		LC	H
Rhynchospora rubra (Lour.) Makino	Cyperaceae		LC	H
Robiquetia succisa (Lindl.) Seidenf. & Garay.	Orchidaceae		V	E
Rourea minor (Gaertn.) Leenth.	Connaraceae		LC	S
Rungia pectinata (L.) Nees	Acanthaceae	Pindi	LC	H
Saccharum arundinaceum Retz.	Poaceae	Teng	LC	H
Saccharum spontaneum L.	Poaceae	Kash, Kaichcha	LC	H
Sacciolepis indica (L.) A. Chase	Poaceae		LC	H
Sacciolepis myosuroides (R. Br.) A. Camus	Poaceae		LC	H
Sagittaria sagittifolia L.	Alismataceae	Chhotokut	LC	H
Sapium baccatum Roxb.	Euphorbiaceae	Cham phata	LC	T
Saprosma ternatum (Wall.) Hook. f.	Rubiaceae	Karful Gachh	E	T
Sarcochlamys pulcherrima Gaudich.	Urticaceae	Jangallya shak	NE	T
Schima wallichii (DC.) Korth.	Theaceae	Konak	LC	T
Schizostachyum dullooa (Gamble) R. Majumdar	Poaceae	Dolu Bansh	NER	S
Schoenoplectus articulatus (L.) Palla	Cyperaceae	Putputi-chechra	LC	H
Schoenoplectus juncoides (Roxb.) Palla	Cyperaceae		LC	H
Scindapsus officinalis (Roxb.) Schott	Araceae	Gaj-pipul.	LC	C
Scleria corymbosa Roxb.	Cyperaceae		NE	H

Botanical Name	Family	Local Name	Conservation status	Habit
Scleria levis Retz.	Cyperaceae		LC	H
Scleria lithosperma (L) Swartz	Cyperaceae		NT	H
Scleria oblata S.T. Blake	Cyperaceae		LC	H
Scoparia dulcis L.	Scrophulariaceae	Bondhone	LC	H
Scurrula gracilifolia (Roxb. *ex* Schult.) Danser	Loranthaceae	Pargacha	LC	P
Senna alata (L.) Roxb.	Caesalpiniaceae	Dadmardon	LC	S
Senna hirsuta (L.) Irwin & Barneby	Caesalpiniaceae		NE	H
Senna occidentalis Roxb.	Caesalpiniaceae	Bara-chalkesunda	LC	H
Senna siamea (Lamk.) Irwin & Barneby	Caesalpiniaceae	Minjiri	LC	T
Senna tora (L.) Roxb	Caesalpiniaceae	Teraj, Chakunda	LC	H
Setaria barbata (Lamk.) Kunth	Poaceae		NE	H
Setaria palmifolia (Koen.) Stapf	Poaceae	Urodhan	LC	H
Setaria sphacelata (Schum.) Stapf. & C.E. Hubb. *ex* M. B. Moss	Poaceae		CD	H
Shorea robusta Roxb. *ex* Gaertn. f.	Dipterocarpaceae	Sal, Gazari	LC	T
Sida cordifolia L.	Malvaceae	Berela	LC	H
Sida mysorensis Wight. & Arn.	Malvaceae		LC	H
Siphonodon celastrineus Griff.	Ceratophylla-ceae	Beljam	NE	T
Smilax ocreata A. DC.	Smilacaceae	Kumarilata	NT	C
Solanum americanum Mill.	Solanaceae	Tit-begun	LC	H
Solanum torvum Swartz, Nov.	Solanaceae	Tit begun	LC	S
Spatholobus acuminatus Benth.	Fabaceae	Tarjanlata	V	C
Spatholobus parviflorus (Roxb. *ex* DC.) O. Kuntze	Fabaceae	Goalia lata, Sal lata	LC	C
Spermacoce latifolia Aublet	Rubiaceae	Ghuiojhil Shak	LC	H
Sphaeranthus indicus L.	Asteraceae	Chagul-nadi	LC	H
Sphenoclea zeylanica Gaertn.	Sphenocleaceae	Jhil Marich	LC	H
Spilanthes calva DC.	Asteraceae	Surja Kannya.	LC	H
Spondias pinnata (L.f.) Kurz	Anacardiaceae	Bon-Amra, Piala	LC	T
Staurochilus ramosum (Limdl.) Scidenf.	Orchidaceae		LR	E
Staurogyne argentea Wall.	Acanthaceae		NE	H
Stenochlaena palustris (Burm. f.) Bedd.	Stenochlaenaceae	Lata Dhekia	LC	F

Botanical Name	Family	Local Name	Conservation status	Habit
Stephania glabra (Roxb.) Miers	Menispermaceae	Thanda Manik	V	C
Sterculia foetida L.	Sterculiaceae	Baro Udal	NE	T
Sterculia hamiltonii (O. Kuntze) Adelb.	Sterculiaceae		LC	T
Sterculia villosa Roxb. *ex* Smith	Sterculiaceae	Chandul	LC	T
Stereospermum colais (Buch.-Ham. *ex* Dillw.) Mabberley.	Bignoniaceae	Dharmara	NE	T
Steteospermum suaveolens (Roxb.) DC.	Bignoniaceae	Kuicha Sunalu	LR	T
Steudnera discolor N. E. Br.	Araceae		V	H
Stictocardia campanulata (L.) Merr.	Convolvulaceae		LC	C
Streblus asper Lour.	Moraceae	Sheora, Harba	LC	T
Strophanthus wallichii Decne.	Apocynaceae		V	S
Suregada multiflora (A. Juss.) Bail	Euphorbiaceae	Bon-Naringa, Moricha	NE	T
Swietenia mahagoni (L.) Jacq.	Meliaceae	Mahagoni	LC	T
Swintonia floribunda Giff.	Anacardiaceae	Civit	V	T
Synedrella nodiflora (L.) Gaertn.	Asteraceae		LC	H
Syzygium balsameum (Wight) Walp.	Myrtaceae	Buti Jam	LC	T
Syzygium claviflorum (Roxb.) A. M. Cowan & J. M. Cowan	Myrtaceae	Lamba Nali Jam	LC	T
Syzygium cumini (L.) Skeels.	Myrtaceae	Kalo Jam	LC	T
Syzygium cymosum DC.	Myrtaceae	Khudi Jam	NE	T
Syzygium firmum Thw.	Myrtaceae	Dhaki jam	LC	T
Syzygium fruticosum DC.	Myrtaceae	Puti Jam	LC	T
Syzygium ramosissimum (Blume.) Balakrishnan	Myrtaceae	Khorjam	NE	T
Syzygium syzygioides (Miq.) Merr. & L. M. Perry	Myrtaceae	Kharijam, Jonkijam	DD	T
Syzygium tetragonum Wall. *ex* Kurz.	Myrtaceae	Pholda jam, Lal Pholda	NE	T
Tabernaemontana crispa Roxb. *ex* Wall.	Apocynaceae	Jangli Tagor	NT	S
Tabernaemontana divaricata (L.) R. Br. *ex* Roem. & Schult	Apocynaceae	Tagar, Dudh phul	LC	S
Tamarindus indica L.	Caesalpiniaceae	Tentul	LC	T
Tarenna campaniflora (Hook. f.) Balakrishnan	Rubiaceae	Harula, Haru Lodi	DD	T
Tarenna disperma (Hook. f.) Pitard.	Rubiaceae		E	S

Botanical Name	Family	Local Name	Conservation status	Habit
Tectona grandis L.f.	Verbenaceae	Shegun	LC	T
Tephrosia candida DC.	Fabaceae	Bilakshani, Bilokhoni,	LC	S
Tephrosia purpurea (L.) Pers.	Fabaceae	Bon-neel.	LC	H
Terminalia alata Heyne *ex* Roth	Combretaceae	Asal, Asma, Hasna	NER	T
Terminalia arjuna (Roxb. *ex* DC.) Wight & Arn.	Combretaceae	Arjun	V	T
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Bohera	LC	T
Terminalia chebula Retz.	Combretaceae	Haritaki	V	T
Tetrameles nudiflora R. Br.	Datiscaceae	Chandul	NE	T
Tetrastigma leucostaphyllum (Dennst.) Alston *ex* Mabb.	Vitaceae	Horina-lata	NE	C
Thladiantha cordifolia (Blume) Cogn.	Cucurbitaceae		LC	C
Thysanolaena maxima (Roxb.) O. Kuntze	Poaceae		LC	H
Toona ciliata M. Roem	Meliaceae	Chondon Suruj	CD	T
Tournefortia roxburghii C. B. Clarke	Boraginaceae	Shamshog	NT	S
Tragia involucrata L.	Euphorbiaceae	Chotra pata	LC	C
Trema orientalis (L.) Blume.	Ulmaceae	Jiban, Naricha	LC	T
Trewia nudiflora L.	Euphorbiaceae	Latim gach, Pitali	LC	T
Trichosanthes tricuspidata Lour.	Cucurbitaceae	Makal	LC	C
Tridax procumbens L.	Asteraceae	Tridhara, Tridaksa	LC	H
Triumfetta rhomboidea Jacq.	Tiliaceae	Banokra	LC	S
Uraria crinita (L.) Desv. *ex* DC.	Fabaceae	Dieng-kha-riu	NER	S
Urena lobata L.	Malvaceae	Ban-okra	LC	S
Uvaria cordata (Dunal) Alston	Annonaceae	Gagh-ranga	NE	S
Vallaris solanacea (Roth) O. Kuntze	Apocynaceae	Hadpur, Hapormali	CD	S
Vatica lanceaefolia (Roxb.) Blume.	Dipterocarpa-ceae	Sutagola, Mohal	NE	T
Vernonia cinerea (L) Less.	Asteraceae	Kuksim	LC	H
Vigna adenantha (Meyer) Marechal *et al.*	Fabaceae	Bon Barboti	LC	C
Vitex glabrata R.Br.	Verbenaceae	Goda arsol	LC	T

Botanical Name	Family	Local Name	Conservation status	Habit
Vitex peduncularis Wall. *ex* Schauer	Verbenaceae	Goda	NER	T
Vitex pinnata L.	Verbenaceae	Goda Horina	NER	T
Walsura robusta Roxb.	Meliaceae	Bon Litchi	LC	T
Waltheria indica L.	Sterculiaceae		NER	H
Wattakaka volubilis (L.f.) Stapf	Asclepiadaceae	Madhumalati	LC	S
Wendlandia tinctoria DC. Subsp. *orientalis* Cowan	Rubiaceae	Rong Ghittya	DD	S
Wikstroemia indica (L.) C.A. Mey.	Thymelaeaceae		NE	S
Wissadula contracta (Link) R.E. Fries	Malvaceae		LC	S
Woodfordia fruticosa (L.) Kurz	Lythraceae	Dhatriphul, Ragkat	DD	S
Wrightia arborea (Dennst.) Mabb.	Apocynaceae	Dudhi, Dudh kurus	NT	T
Zanthoxylum rhetsa (Roxb.) DC.	Rutaceae	Bajna, Bazinali	LC	T
Zingiber capitatum Roxb.	Zingiberaceae	Jongli Ada	NER	H
Zingiber zerumbet (L.) Smith.	Zingiberaceae	Bon Ada	LC	H
Ziziphus oenoplia (L.) Mill.	Rhamnaceae	Bonboroi	LC	S
Ziziphus rugosa Lamk.	Rhamnaceae	Jangli Boroi	NE	S

*C = Climber, E = Epiphytes, F = Ferns, H = Herb, P = Parasite, S = Shrub, T = Tree, CD = Conservation Dependent, DD = Data Deficient, EN = Endangered, LC = Least Concern, LR = Lower Risk, NE = Not Evaluated, NER = Not Evaluated but Rare and NT = Near Threatened, V = Vulnerable

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The Use of Biogas Technology in Solving Fuel Crisis and Meeting Organic Fertilizer Demand in Bangladesh

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Abstract

More than 80% of rural population in Bangladesh depend on primitive energy sources and only 8% people could so far be covered by natural gas supply. The lack of access to efficient energy sources in the developing nation is one of the major obstacles to their development. Despite many challenges, Biogas Technology has been a boon to small farmers as well as to small, medium and large poultry farms. A farmer with 4 cows or 200 poultry birds can construct a biogas plant to have cooking gas, bright light and bioslurry organic fertilizers. Large poultry farms can produce electricity, reduce their energy cost and rent the extra gas to their neighbours. Instalment-based monthly payments over two or three years have reduced the upfront cost of a biogas plant and have made it an attractive investment. Biogas technology is becoming slowly popular among the rural people. Over 20 biogas villages have been established where around 50% of the villagers have set up biogas plants. Around 28,000 biogas plants have been constructed under BCSIR and LGED initiatives from 1996 to 2004 and around 40,000 biogas plants were also constructed from 2006 till now as a result of promotional activities and financial support by IDCOL, SNV, GTZ and other organizations. A biogas system basically providing three-tier benefits include energy, sanitation (waste stabilization and management) and bioslurry organic fertilizer. Other economic benefits are saving of time and money, clean environment, availability of subsidy and health benefits including the reduction of smoke-borne diseases. Bioslurry organic fertilizer may be used as a supplementary source of chemical fertilizers for maintaining soil health and thereby sustaining crop productivity. Considering the above benefits, all out efforts should be taken by the government to promote, disseminate and utilize this technology to the fullest scale of the satisfaction of the users.

Introduction

Bangladesh is a densely populated country facing many challenges such as energy crisis, food production and security for more than 160 million people. It is one of the very low-energy consuming countries of the world where only 60% of the total population has access to electricity and only less than 8% people are enjoying piped gas supply. The per capita energy consumption is only 220 kg of oil equivalent (kgoe).

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On the other hand, Bangladesh is forced to maximize crop yields per unit area through intensive use of soil and land resources for her ever increasing population from limited cultivable land. As a result, continuous mining of nutrients from the soil is going on. Due to such intensification, the fertility of the soils has been declining day by day. Many soils are losing their productivity. The use of chemical fertilizers and pesticides without any Organic fertilizers causes serious problems to the soils such as hardness, low water-holding capacity, micro nutrient deficiencies, reduced soil microbial activities, etc. Therefore, biogas can be a very important renewable energy source for the country. If the cow dung of 15 thousand cattle farm and individual farmer's cattle along with poultry litters of 215 thousand poultry farms are utilized for biogas production, energy deficit of the country can be met up to a great extent. Moreover, it contributes to the global movement to fight off climate change and curb carbon dioxide emission. Also it reduces the pathogens in homes. Bioslurry released from hydraulic chamber of biogas plant is a good quality organic fertilizer for improvement of soil health. So, the government has given high priority on the construction of biogas plants throughout the country. Quite a good number of non-government organizations (NGO) have also come up to expand the biogas technology. So far about 80,000 biogas plants have been constructed throughout the country. But many of the plants do not produce desired quantity of gas. Qualities of fertilizer of cow dung, poultry litters and household wastes are different that need to be determined to improve the performance of plants. The present paper focuses about the on-going biogas activities within the country as well as utilization status of bioslurry as a fertilizing material for crop production.

Energy Usage and Generation: Current Scenario of Bangladesh

Bangladesh is one of the low energy consuming countries of the world. More than 90% of the people are depending on the biomass, particularly woody type for everyday cooking and other heating purposes. About 50 million tons of biomass fuels such as fuel-wood, branches, straw-leaves, agricultural residues, cow dung cake, briquettes, etc. are being used annually (Islam and Islam, 2011). The situation is extensive in areas where no natural gas supply system exists. Moreover, the alternative fuels like kerosene and liquefied petroleum gas (LPG) are expensive for a majority of the people. Therefore, the largest parts of the country's poor families have to rely on traditional fuels to produce energy. In this context, biomass energy plays a vital role in meeting local energy demand. There are huge number of wood shops supplying woody type biomass fuels in Bangladesh that cause serious deforestation and other environmental problems. Coupled with this, the efforts for planting trees to periodically replace felled-forests are sporadic and extremely rudimentary. This has resulted in accelerated depletion of forests in the country (NRBAR, 2009).

Simultaneously, nearly 40% of its 160 million people do not have access to electricity. Only 8% have access to piped natural gas for household cooking. Thus Bangladesh is one of the bottom listed countries in the context of per capita energy consumption or energy intensity but it is distinctly lucky to have substantial reserve of natural gas and very high quality bituminous coal. At the same time, some developed countries like Japan and Korea have no basic natural energy resources, but they are leading economy; some countries have huge natural resources like Nigeria, Sudan but they are among the poorest of the world. They failed to explore and exploit their resources to the best interest of their nations. Still some countries like Bangladesh have substantial resources but do not have technical or financial capacity of their own to make economic utilization of resources. The riverine delta is also least explored.

The gas industry in Bangladesh is much older than the nation itself as exploration and utilization of natural gas started in early sixties when this region was part of Pakistan. In that sense gas industry is more than 50 years old. There was a brief period of oil use in late eighties and early nineties when the lone gas field in Sylhet was in operation. Utilization of own coal started in 2006. Hydroelectric generation has been in place since late sixties. Solar power generation is gathering momentum; biogas production is also finding its way. The present demand supply imbalance may give momentary wrong signal but the country has enormous potential to not only overcome these tensions but also can become a medium- earning vibrant economy if it only can plan and implement its energy sector development actions with vision and commitments.

Natural gas of Bangladesh accounts for 100% of urea fertilizer production and almost 85% of power generation. This mono fuel-based energy scenario has created a crisis as gas sector and power sector growth did not complement each other over the years. This has resulted in stranded gas in one region and huge hungry demand in others. Exploration and development of gas did not have keeping pace with growing demand. The only other viable option coal mining did not achieve mentionable success so far. However, the good part is that promotion of and expansion of renewable energy technologies is being taken up to the door steps of millions of off-grid rural people in remote and inaccessible areas by different NGOs and private companies.

Present Programs of Biogas Plants in Bangladesh

Biogas technology, although a potential technology for rural Bangladesh, has not been disseminated up to satisfactory level due to lack of initiative and drive by the government and development agencies. Bangladesh Agricultural University first demonstrated the floating-drum type biogas plant of 3 m^3 in the Department of Agricultural Chemistry in as early as 1972. Later on, few such biogas plants were constructed around Mymensingh for cooking and lighting purposes. In 1976, Bangladesh Academy for Rural Development constructed similar floating-

Bioslurry Processing and Collection

More than 80,000 biogas plants of varying gas-producing capacities (2-6 m^3) run with cow dung and poultry litter for domestic purposes and some large sized ones in poultry farms are in operation in the country. These biogas plants generate more than 800,000 tons of slurry on dry weight basis which is equivalent to about 36,000 tons of urea, 100,000 tons of triple super phosphate (TSP) and 12800 tons of muriate of potash (MoP) plus other secondary and micronutrients

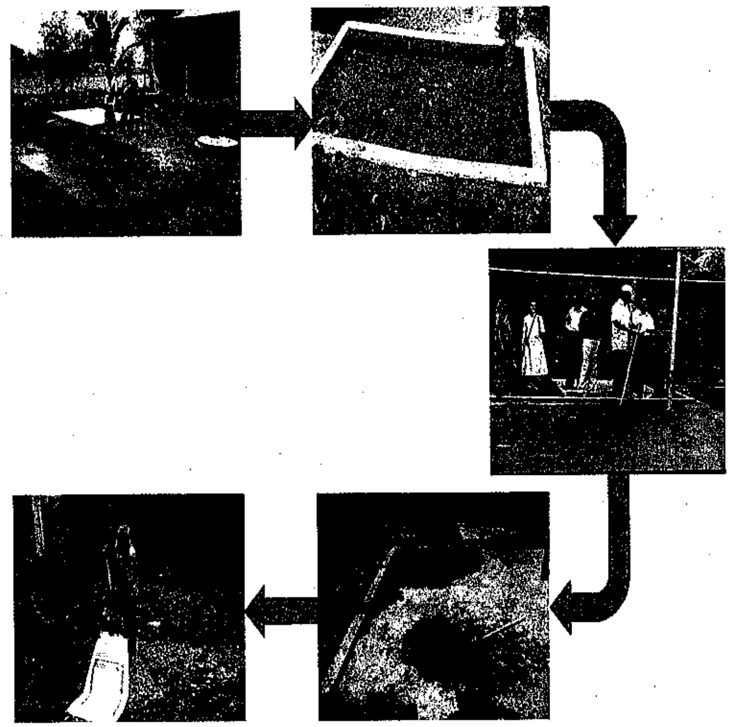

Fig. 2. Bioslurry collection, drying and bagging for marketing

Unfortunately, bioslurry collection at the plant premises is highly unsatisfactory. No proper methodology is followed. As a result, the loss of nutrients from slurry collection point is substantial (Fig. 2).

Utilization of Bioslurry

Bangladesh is an agricultural country and thus soils are its most important natural resources. The heart of this natural resource is organic matter which is called by the scientists as the storehouse of plant nutrients. But the fertility of the soils is deteriorating day by day due to intensive cultivation and imbalanced use of chemical fertilizers. By the time, strong acidity has developed in many of the country's soils. Organic matter content in soils is alarmingly low around 1% in most and 2% in few soils, whereas it should be maintained at least 3% which is

conducive to high crop productivity. To sustain crop productivity and to increase soil fertility, there is no alternative but to add organic fertilizer in the soils.

Bioslurry could be one of the best organic fertilizers to rejuvenate soils since it is a rich source of both plant nutrients and organic matter. Bioslurry when properly processed and applied can increase the physical, chemical and biological properties of the soils besides supplying essential nutrients to the crop plants. It increases the organic matter content of the soils and thus the health of the soils is maintained. The use of bioslurry can reduce the application of chemical fertilizers to a great extent. It is possible to reduce the use of the chemical fertilizers up to 50%. As a result, using reduced doses of chemical fertilizers will benefit the farmers in their costs of production and the soil environment will be in a high fertility and productive state.

In view of the deteriorating soil fertility, organic fertilizers produced from bioslurry are environment friendly and can help to a great extent rejuvenate the soils by supplying considerable amounts of macro as well as micronutrients, and organic matter, which can also improve physical and biological conditions of the soils.

Table 2. Nutrient and heavy metal contents as well as other characteristics of bioslurry of biogas plants.

Nutrient content	Cow dung slurry		Poultry litter slurry	
	BARI values	DU values	BARI values	DU values
	%			
Total Nitrogen	1.35	1.23	2.71	2.75
Total Phosphorus	2.89	2.71	3.35	3.24
Total Potassium	0.88	0.62	0.85	0.75
Total Sulphur	0.71	0.67	1.00	0.91
Total Calcium	0.92	0.80	4.50	3.90
Total Magnesium	0.62	0.72	2.60	2.42
Total Iron	0.103	0.80	0.209	0.198
Total Manganese	0.080	0.09	0.067	0.071
Total Boron	0.069	0.06	0.041	0.050
	$\mu g\ g^{-1}$			
Total Zinc	610	580	717	590
Total Copper	428	450	224	260
Heavy metal				
Total Arsenic	1.47	1.40	1.77	1.32
Total Lead	11.37	12.00	20.09	21.00
Total Cadmium	3.64	4.35	4.28	3.90
Other characteristics				
Moisture (%)	11.25	12.00	11.17	11.79
pH	7.94	8.21	8.31	8.35
Organic matter (%)	26.04	27.78	21.58	30.34
Colour	Brownish		Grayish	
Physical conditions	Powder, free flowing		Powder, free flowing	

The nutrient contents of the commonly used organic fertilizers including bioslurry in the country are shown in Table 2. It is seen that slurry contains more nutrients than the ordinary organic fertilizers (Islam 2006).

The bioslurry can be applied as liquid, air-dried and sun-dried conditions for enhancing the yield of agricultural crops and was also found to be suitable as a seed coating media, fortified with *Rhizobium, Azospirillum*, phosphobacteria and micronutrients which enhances seed germination, seedling establishment and induces vigour to crops. Bioslurry enriched with inorganic fertilizers and biofertilizers such as Rhizobium increases crop productivity and sustains soil fertility.

Organically produced crops and fruits are healthy and nutritious, and have better shelf life as well as higher market value. Demands for organically produced crops are increasing day by day in Bangladesh and elsewhere in the world. Bioslurry organic fertilizers can well be fitted into the modern soil fertility management popularly known as **Integrated Plant Nutrition System**, which combines the use of organic and chemical fertilizers. Thus, the use of bioslurry organic fertilizer can reduce the quantity of chemical fertilizers which may increase acidity/alkalinity in soils and deteriorate their physical conditions.

Results of Field Trials/Demonstrations

Review of the research works carried out in Bangladesh has shown that BARI and Grameen Shakti have done some works on bioslurry organic fertilizers. There are also some sporadic reports on the use of aerobically decomposed cow dung, poultry litter and compost on field and horticultural crops. After the introduction of fertilizer responsive high yielding and hybrid varieties of crops, the use of chemical fertilizers has increased manifolds. But the use of organic manure as a supplementary source of nutrients has been ignored.

Grameen Shakti (2006) conducted an observational field trial in Grey Floodplain soils of Manikganj to study the effects of cow dung (CD) and poultry litter (PL) bioslurry on cabbage, brinjal and tomato during the Rabi (winter) season of 2005-06. Treatment combinations were: Control (native fertility), 100% RD (recommended dose), and 50% RD + CD bioslurry (2t/ha), 50% RD+PL bioslurry (2t/ha), 10% RD+ CD bioslurry (2t/ha) and 10% RD+ PL bioslurry (2t/ha). Sun-dried bioslurry was added at the rate of 2 tons/ha in two installments-first installment was applied along with chemical fertilizers at the time of planting and the second installment as top dressed after 30 days of planting. All the crops responded dramatically to added bioslurry. The results of the field trials are summarized in Table 3.

Table 3. Effect of cow dung and poultry bioslurry on the yield of cabbage, brinjal and tomato at Manikganj

Treatment	Cabbage (t/ha)	Brinjal (t/ha)	Tomato (t/ha)
Control (native fertility)	10.00	5.50	6.50
100% RD	56.50	26.30	24.00
50% RD+CD bioslurry	58.60	24.00	25.00
50% RD+PL bioslurry	60.00	25.00	27.00
10% RD+CD bioslurry	44.00	15.00	16.00
10% RD+PL bioslurry	48.00	17.00	18.50

CD- Cow dung, PL- Poultry litter, Recommended dose (RD) for Cabbage- N_{200} P_{60} K_{120} S_{30} kg/ha, RD for Brinjal- N_{150} P_{60} K_{120} S_{30} kg/ha and RD for Tomato- N_{150} P_{60} K_{120} S_{30} kg/ha.

Fig. 3. Use of bioslurry in tomato field

It is quite evident from Table 3 that bioslurry had favorable influences in increasing the yields of the crops under study. The yield responses were comparable with those of recommended fertilizer doses. It is possible to reduce the application of chemical fertilizers up to 50%. Between the two, poultry litter bioslurry proved superior to cow dung bioslurry because of presence of more nutrients in it. In another trial with papaya conducted in Grey Terrace soils at Bhawal Mirzapur, Gazipur, poultry litter bioslurry produced better effects than the cow dung on the yield of papaya. It was noted that fruits obtained from bioslurry applied plots were sweeter than that of chemical fertilizers applied plots.

Raj Poultry farm (2006) has been demonstrating its bioslurry on onion (var. Taherpuri). The remarkable yield increase of onion was obtained applying bioslurry. With application of 50% recommended dose (N_{120} P_{40} K_{60} S_{20} kg/ha) plus 1 ton bioslurry/ha, 1.5 times more yield (15-17 t/ha) of onion was obtained in 2006 than that with only chemical fertilizers. Majumder (2006) enriched K content in bioslurry of his 6-biogas plants through feeding chopped water hyacinth along with cow dung and poultry litter as raw materials. He used bioslurry for production of seed potato and table potato. With application of 2 tons of slurry along with only 20 kg N/ha, 20 tons of seed potato plus 5 tons of table potato was obtained. The yield of the crops is higher than those grown with recommended chemical fertilizers. The reduction of the use of chemical fertilizers is significant.

Uddin *et al.* (2005) found that boro rice variety BRRI dhan29 produced highest grain yield (7.50 t/ha grain yield) compared with other rice varieties when fertilized with poultry manure (5t/ha) + urea super granule (175 kg/ha).

Noor et al. (2005) evaluated some organic manure on the yield of cabbage using integrated nutrient management system during the Rabi seasons of 2000-2001 and 2001-2002 in Grey Terrace soils of BARI central farm. The highest mean yield (87.10 t/ha) was obtained from treatment 70% RD + 5 t oil cake/ha which was significantly higher over all other treatments except treatment 70% RD +10 t poultry manure/ha and 70% RD + 2.5 t oil cake/ha treatments (Table 4). The second highest mean yield (84.75 t/ha) was obtained from treatment 70% RD + 2.5 t oil cake/ha followed by treatment 70% RD +10 t poultry manure/ha, which was statistically identical with the treatment 70% RD + 5 t oil cake/ha.The treatment package 70% RD +5 t poultry manure may be recommended for the marginal farmers whereas resource rich farmers may use either treatment 70% RD + 2.5 t oil cake/ha or treatment 70% RD +10 t poultry manure/ha for higher yield.

Table 4. Yield of cabbage (t/ha) as affected by integrated nutrient management system during Rabi seasons of 2000-2001 and 2001-2002

Treatment	2000-2001	2001-2002
100% RD	67.36	61.82
70% RD	52.86	45.2
70% RD+ Cow dung (5 t/ha)	60.44	57.22
70% RD+ Cow dung (10 t/ha)	70.76	65.56
70% RD+ Poultry manure (5 t/ha)	73.32	74.86
70% RD Poultry manure (10 t/ha)	81.28	81.80
70% RD + Oil cake (2.5 t/ha)	84.88	84.62
70% RD + Oil cake (5 t/ha)	87.25	86.94
Native fertility (Control)	22.14	19.74
CV (%)	5.6	6.4

RD= Recommended dose-N_{250} P_{36} K_{80} S_{40} B_2 Mo_1 kg/ha

The Contribution of Biogas Technology to Conservation of Environment

The conversion of waste material into fertilizer and biogas helps protect the environment in five principal ways:

The generated biogas can replace traditional energy sources like firewood and animal dung, thus contributing to combat deforestation and soil depletion.

- Biogas can contribute to replace fossil fuels, thus reducing the emission of greenhouse gases and other harmful emissions.
- By tapping biogas in a biogas plant and using it as a source of energy, harmful effects of methane on the biosphere are reduced.
- By keeping waste material and dung in a confined space, surface and groundwater contamination as well as toxic effects on human populations can be minimized.
- By conversion of waste material and dung into a more convenient and high-value fertilizer (biogas slurry), organic matter is more readily available for agricultural purposes, thus protecting soils from depletion and erosion.

Conclusions and Recommendations

Biogas technology is simple, environment friendly and has been accepted socially by the people in the country. This technology recycles decomposable organic resources, conserves biodiversity and ensures appropriate use of biomass. In view of growing energy crisis in the rural Bangladesh, this technology should be promoted with all-out efforts by the government agencies, private companies, different NGOs as well as philanthropic organizations without any delay. Biogas technology not only provides energy for multiple uses, but also supplies good quality slurry that can be used as organic fertilizer in our hungry soils. Slurry supplements soils not only with NPK nutrients but also with secondary and micronutrients, and improves soil conditions conducive to high crop productivity. From these plants, a huge quantity of organic fertilizers are obtained for soil application and thus the use of chemical fertilizers could be reduced significantly up to 40-50 % or even more. Due to high oil prices in the international market and shrinking natural resources for fertilizer production, the prices of the imported fertilizers will continue to increase in coming years. Under such situations, in order to harness the immense potential opportunities of biogas technology, the government should come forward and provide at least, if not more, 50% subsidy to biogas programs and thus encourage private companies/NGOs that are engaged in promoting biogas technology for solving growing fuel crisis in rural households as well as supplementing costly chemical fertilizers in crop productivity.

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