Sustainable Food Production
ISSN: 2624-876X, Vol. 4, pp 1-10
doi:10.18052/www.scipress.com/SFP.4.1

Submitted: 2018-09-11
Accepted: 2018-12-05
Online: 2018-12-20

Assessing Traditional and Sustainable Harvesting Methods on the Collection of Two Leading Non-Timber Forest Products - *Griffonia simplicifolia* and *Xylopia aethiopica* - In Liberia

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Keywords: Traditional harvesting methods; Sustainable harvesting; Forest resources; Non-Timber Forest Products; *Griffonia simplicifolia; Xylopia aethiopica*

Abstract. Traditional harvesting methods of Non-Timber Forest Products (NTFP) are known to be destructive and/or wasteful that lead to reduction and sometimes depletion of the population and the biodiversity. Sustainable harvesting however is not only necessary for conservation of biodiversity, but also the livelihoods of many rural peoples in forest areas for their sustenance. Sustainable harvesting increasingly acknowledged as a conservation strategy can easily be employed for plants that require seeds harvest as product, such as Griffonia and Xylopia. The harvesting of these plant products requires a practical method and a change of behavior pattern towards sustainability. Change in behavior patterns with corresponding modifications in harvesting techniques can create a win-win strategy for harvesters and the biodiversity. The study describes current methods for harvesting two important Liberian plant species (*Griffonia simplicifolia* and *Xylopia aethiopica*) and suggested alternative (proposed sustainable) technique and their impact on the population in two harvesting seasons. In the first and second harvest seasons, using traditional methods, an average total of 34.6 kg of Xylopia and 22.7 kg of Griffonia pods were collected; while using alternative methods, an average total of 52.5 kg of Xylopia and 34.7kg of Griffonia pods were collected. Equally using the traditional method, an average total number of 87 trees of Xylopia and 85 vines of Griffonia were damaged, while an average total number of 12 trees of Xylopia and 10 vines of Griffonia were damaged using the 'proposed sustainable' method. Changes in behavior pattern of local collectors incorporating the 'proposed sustainable' alternative method of collection lead towards a win-win situation with added value of preservation.

Introduction

Traditional harvesting methods are known to be destructive and/or wasteful leading to reduction of Non-Timber Forest Products [42, 12] and sometimes depletion of population and biological diversity [8, 19]. Non-Timber Forest Products, or known as NTFP, refer to a wide collection of economic or livelihood materials that come from forests, excluding timber [42]. de Beer and McDermott [43] also defined it as "encompassing all biological materials other than timber, which are extracted from forests for human use". These include fruits, nuts, mushrooms, essential oils, florals, medicinal products, herbs and spices, dyes, resins, and animal products such as honey, fish and wild game, as well as fuelwood [44, 45].

Studies have shown survival and continual production risks to NTFP from wild harvesting due to increasing demands [4, 3, 22, 36] extended uses [39], and trading [13, 8, 2]. Heightening threats to NTFP also include deforestation from logging [9], conversion to plantations [15], pasture and agriculture [17, 29], habitat modification due to urbanization [18, 38], and traditional patterns of unsustainable rates of exploitation [9, 4, 7, 40, 33], coupled with the rapidly increasing human population [2]. These threats may result in ecological problems including resource depletion [25], as well as species endangerment and extinction [20, 1, 28]. Those who are most economically

reliant on natural resources tend to be local community dwellers. Sustainable harvesting is therefore not only necessary for conservation of plant biodiversity, but also for the livelihoods of many rural peoples in those forests that are at risk [32, 34, 35, 39].

There has been discussions and debates as to whether NTFP harvest is intrinsically, or can possibly be, sustainable and ecologically more benign [31, 37]. Ecologically, harvesting can be considered sustainable at the species level if there is no long-term deleterious effect on the reproduction and regeneration of the plant populations being harvested [37]. Equally, harvesting should also not have any visible adverse effect on other species within the same region, or on ecosystem structure and/or function [16, 39]. The harvesting of fruits and seeds, though not immediately harmful, can affect the future regeneration of a species [16]. The harvesting of bark and other woody parts of plants can cause short to long-term senescence and, ultimately, the death of the plant [27, 30]. Moreover, if a plant is uprooted or felled for the collection of any parts whatsoever leads to the destruction of the plant and eventual decline overtime [11, 19].

The parts of Griffonia (Gri*ffonia simplicifolia* (M.Vahl ex DC.) Baill.) and Xylopia (*Xylopia aethiopica* [Dun.] A. Rich.) harvested are the pods, though other parts have been used in traditional medicine including the bark and leaves for Xylopia [6], and the bark, leaves, and roots for Griffonia [10, 23, 5]. In Liberia and in context to these species Juliani et al. [19] have reported local collectors harvesting only the pods by cutting down trees and vines of Xylopia and Griffonia, respectively, to collect pods from their branches. This may be due to the lack of knowledge of alternative sustainable harvesting practices and the benefits thereof to sustainability and conservation of the populations. Juliani et al. [19] had reported that there was a lack of understanding by the local communities and collectors of the importance of sustainability since most of the plants used are wildly harvested and there was not a connection between how they harvested these species for trade and commerce with their regrowth. Kpadehyea et al. [21] also suggested that the idea of plant collection in the Ziama, Wonegizi Clan in Lofa County is poorly understood.

While Griffonia has a one season harvest period per year (November to May) [19], Xylopia fruits twice and thus has two season fruiting periods per year, December to March and June to September [26]. The collection of products by cutting entire plant is more sensitive to the plant growth over time, even with regeneration potential. Juliani et al. [19] had reported current local harvesting practices of Xylopia being destructive and involving the cutting down of the entire tree to collect the fruits, as well as using the stems for poles as building material. Similar trend has also been noted for Griffonia, as collectors employed related destructive method by pulling down vines or cutting of tree that contained the climber plant in order to gather the pods to collect the seeds [19]. Thus, the harvest of these NTFP require a practical sustainable harvesting method and a change of behavior pattern towards sustainability.

Sustainable harvesting which is increasingly acknowledged as a conservation strategy for most wild harvested plants, with long-term valuable contributions to local economies and harvesters [33] can be employed for species plants that require only seeds harvest as product, such as Griffonia and Xylopia. Manvell [24] had recommended exploring and developing harvesting methods for sustainable production of NTFP in Liberia. The sustainable collection of NTFP is important in the preservation of forest biodiversity while also benefiting longer-term productivity and income, with many scientific studies reporting ecological effects of NTFP harvesting [27, 8, 39]. In Liberia, however, limited studies about the ecological effects of NTFP harvest [19, 21] and rarely any systematically scientific investigation on sustainable harvesting technique have been reported. Changes in harvesting patterns with corresponding modifications in harvesting techniques can create a win-win strategy, where local people benefit while conserving the forest biodiversity [14].

To understand and incorporate changes in harvesting patterns with sustainability of Liberian NTFP for longer-term income generation and biodiversity conservation, the objectives of this study were to describe and assess current methods for harvesting two important Liberian NTFP and suggested alternative sustainable technique of harvesting and to assess the impact of the harvesting methods on species population.

Materials and Methods

Two field plots of forest areas with size of 4,047 m^2 each were used to test the effects of two collection methods for two Liberian NTFP, Griffonia (*Griffonia simplicifolia*, in the Zor Community forest) and Xylopia (*Xylopia aethiopica*, in the Raymond Town Community forest), over two consecutive production seasons from December 2015 to January 2017. The forest areas were selected because of the species richness visually found in the individual locations, and also because of the willingness of the community leaders and in accordance with the community members to allow the use of their forest to be used for the study. Each forest plot was divided into eight (8) blocks; four (4) blocks from each of the forest plots were used for one collection method, the local harvesting method; and the other four blocks used for another collection method, the alternative harvesting method. Three (3) trees (Xylopia) or vines (Griffonia) per block were randomly selected, marked with flag tape and used for the collection during two harvesting seasons. Tools and methods used traditionally by local collectors included cutlasses and collection bags and/or tubs. With cutlass, trees or vines were easily cut down in order to reach the pods. In most cases, paths were created to get to a tree of Xylopia or vine of Griffonia; in the process, most vegetation including young growing Xylopia or Griffonia plants would be cut. Cutting of tree and vine often had other plant accompanying the fall. However, only Xylopia or Griffonia plants that were damaged were visually counted to record impact on plant species population.

The first method or the local harvesting method, which was considered as the traditional harvesting method (as has been the only known method by local collectors for harvesting fruits that would be difficult to reach with hands), local collectors often collected pods of Xylopia or Griffonia by cutting down almost the entire plant in order to reach and collect the fruits, while only sparing branches that would be at reachable area for hand picking of fruits; only these branches would be left for production during the following season. Ten local collectors were selected for practice of this method for each forest; two persons per block for four block, while the remaining two persons were assigned to weighing the harvested products as well as the count of the damage of Xylopia or Griffonia plant from each of the forests.

The second method, which was considered an alternative harvesting method to the traditional way of harvesting either of the two plants, required training of collectors to practice a method that would minimize damage to the plant, but generate maximum collection. For this purpose, ten members from each of the two communities were selected and trained in the use of this method. These members were another group of local collectors being trained. This alternative harvesting method included using appropriate tools such as sickled serrated blades for harvesting hanging pods on tall trees or vines that have climbed on trees, in this case, a tapping knife (i.e. a rubber tree tapping knife that is used for latex extraction) sharp from tip to curve, tied to the end of a long bamboo stick along with a collection bag attached below the knife to enable harvested pods to fall directly in bag; others falling to ground would easily be picked from the ground floor with hand. The long bamboo was intended to easily reach to pods at distant branches either from the ground or at a reachable climbing location in the tree. A test trial was demonstrated for further clarity and to enable trainees to grasp the idea of the concept. Each member was allowed to perform the demonstration one at a time to show proof and ascertain clarity of knowledge. Purchased tapping knives were then distributed to each member who made his/her own picking stick. Each member was told to collect upon harvest as much as possible as they could reach, but be sure to let few pods on trees or vines to mature for seeds regeneration process [16]. By this, the plants would have more new growths to replace for old-aged plants.

For each of the four blocks in each of the two forest areas, two trained persons were allowed to collect from three trees for Xylopia or three vines for Griffonia. During the first harvest season, eight trained persons collected from the four blocks in each forest plot; during the second collection season, the eight trained persons rotated in each of the four blocks per forest plot, while the two persons who remained were assigned to the weighing and count of damage Xylopia or Griffonia plants during harvests.

For the first collection method, the traditional method, using the selected 4 blocks from each of the two forest plots, local collectors followed traditional ways of harvesting the pods; collectors gathered and weighed (Kg) the harvest collected from the selected trees (Xylopia) or vines (Griffonia) within each of the four blocks that was selected for traditional method practice. For the second method, using the other 4 blocks from each of the forest plots, the group of local collectors who were trained followed the alternative harvesting method that would minimize damage to trees and/or vines. These collectors gathered and weighed (Kg) the harvest collected from the selected trees (Xylopia) or vine (Griffonia) within each of the four blocks that was selected for the use of alternative harvesting method.

For the two collection methods, collection impact was assessed by the visual observation and count of tree or vine damage generated during the two collection practices, in relation to the total number of plants in each block. After each harvest season, impact on the plant species was recorded by visual observation and count of damaged plant species within each block.

The season collection date for Xylopia was February 18–22, 2016, while second collection date was July 6–10, 2016. For Griffonia, first season collection was March 7–12, 2016, while second season collection date January 6–11, 2017.

All produce collected were given to local collectors who dried products in sun and sold to collecting agents at affordable price rates (LD$ 100 per kilo for Xylopia seeds, and LD$ 250 per kilo for Griffonia; LD$100 = US$1.00).

Experimental design and analysis

The study used randomized complete block design (RCBD) for field experiment to test effects of collection methods for NTFP harvests. Data collected were compiled, computerized in excel spreadsheet and subjected to statistical analysis, using Microsoft Excel Data Analysis Tools.

Results and Discussion

During first collection season, local collectors harvested a total average of 28.3 kg of Xylopia pods from the total of 12 trees selected in the plots using the traditional method of harvesting (Table 1). Collectors using the alternative ("proposed sustainable harvesting") method that should minimize damage to the plants harvested slightly lower amounts (26.2 kg) (Table 1). However, during the second season, collectors using the traditional method harvested on average only 6.3 kg; while collectors using the alternative, 'proposed sustainable harvesting', method obtained similar yields (26.5 kg) as that collected during first season in relation to the traditional method (6.3 kg) (Table 1). This supports the recommendation by Manvell [24] to explore and develop harvesting techniques for sustainable production of NTFP in Liberia and that when done correctly it need not impact yield and income generation.

Table 1. Collection of the fruits of Xylopia (Xylopia aethiopica) and Griffonia (Griffonia simplicifolia) using traditional and alternative methods of harvesting for two harvesting seasons (unit in kilograms).

Harvest	Xylopia Pods (kg)		Griffonia Pods (kg)	
	Traditional method	Alternative method	Traditional method	Alternative method
1st harvest season	28.3	26.2	18.5	17.1
2nd harvest season	6.3	26.5	4.2	17.6
Total	**34.6**	**52.7**	**22.7**	**34.7**

After the second season, collectors were able to increase the total yields from 34.6 kg for the traditional method to 52.7 kg for the improved method of collection. The results showed that collection impact on the trees was much higher using traditional methods (Table 1). The improved method of collection is a practical sustainable harvesting technique that uses methods and tools that minimize damage to the plant. Thus, changes in behavior pattern of local collectors to incorporating the improved method of collection lead towards sustainable practice of collection, which is evident given the ability of the plants to bear fruits, affirming statement by Schippmann et al. [33].

For Griffonia, we observed a similar trend. By using the traditional method, higher yields were observed during the first season (18.5 kg) and a decrease in yield during second season (4.2 kg) (Table 1). The proposed sustainable harvesting technique yielded 17.1 kg in the first season and a similar result (17.6 kg) during the second harvest season. Overall yields were again higher for the improved method (34.7 kg vs 22.7 kg for the traditional) (Table 1). The traditional way of harvesting has been practiced from time in memorial by local community dwellers who are involved in the collection of the plant product. Those using the improved methods were group of local community members who were trained to use materials and tools that would minimize damage to plant but enable maximum harvest. These people have not practiced such method before until the beginning of the study.

Table 2. Collection impact assessed by visual observation of Xylopia (Xylopia aethiopica) tree damage and Griffonia (Griffonia simplicifolia) vines damage (number of damaged trees and vines) using the traditional and alternative methods of harvesting for two harvesting seasons.

Harvest	Number of Damaged Trees of Xylopia		Number of Damaged Vines of Griffonia	
	Traditional method	Alternative method	Traditional method	Alternative method
1st harvest season	59	10	55	9
2nd harvest season	28	2	30	1
Total	**87**	**12**	**85**	**10**

In the first season using traditional method, 59 Xylopia trees were damaged, while in the second season an additional 28 Xylopia trees were damaged (Table 2) in relative to 3 trees/vines/block/4 blocks. The end result for the improved method is the fact that for two seasons, increased yields were observed, with the added value of preserving the resource. These results provide support for the conclusions/recommendations of Ghimire et al. [14], which states a win-win strategy when there are changes in harvesting patterns with corresponding modifications in harvesting techniques, where the local communities benefit while conserving the forest biodiversity.

The results also showed that collection impact and damage to Griffonia vines was much higher using the traditional methods, with 55 vines being damaged during first season of harvest and another 30 vines damaged in the second season of harvest (Table 2). Due to lack of knowledge on how to harvest [19], the results in Table 2 confirmed traditional harvesting techniques in these two communities to be destructive and wasteful. Over a long-term of repeated harvesting technique, such results could lead to reduction in said NTFP and potential destruction or some loss of biological diversity due to cutting that often takes along other plants during its fall [42, 12]. The results from the collection using traditional method of harvesting resulting in damage of plant species anticipates a probable depletion of harvested plant species over time with continual harvesting practice (Table 2). Studies by Cunningham [8] and Juliani et al. [19] have reported that traditional methods can lead to depletion of plant population and biological diversity. Cutting of trees of Xylopia or vines of Griffonia resulted in the plant's inability to replenish over a season's

period to produce desired yield. Sustainable harvesting would have a continual yield for continual harvest for every production season, while unsustainable harvesting would tend to reduce harvesting result from one season to the next (Table 1). Sustainability requires that human activity only uses nature's resources at a rate at which they can be replenished naturally, with a change in behavior pattern toward sustainable harvesting practices for collection of various NTFP.

The evidence of threat due to unsustainable rates of exploitation was realized, as reported by Bodeker [4] and Schippmann et al. [33], in the assessment of impact due to traditional method of harvesting that resulted in limited yields during the second harvest seasons for both species (Table 1). During first harvest season, local collectors harvested pods from trees by cutting the trees of Xylopia in order to obtain pods from all branches that had fruits. They were very successful in collecting high quantity of pods. However, they did not consider subsequent season for harvest, nor awareness of cutting of trees and effect on plant. During the second harvest season, when they were told to only harvest from the very same trees that were harvested the previous season, it became clear that only branches that were left on bottom stems had fruits that could be harvested; hence, the decrease in yield collection in second season (Table 1). Similar situation was seen for Griffonia harvest, when local collectors practicing traditional way of harvesting either cut or pulled entire vine down only to harvest hanging pods during the first season. Quantity collected was astounding; however, second harvest season saw the exact opposite for quantity obtained due to very limited fruits that that developed from the uncut vines, while cut vines were no more productive nor alive for production. They still exerted all efforts to harvest the little that were seen on left vines either by pulling to ground or cutting to reach pods. There was however very limited pods that were collected; hence, the decreased quantity (Table 1). Impact on plant species and population was also seen when entering forest to collect, where a collector would make paths to reach a tree or vine to harvest, thereby cutting young growths. Also cutting of tree or vine would take along with its fall others, all of which were impacted.

The harvesting of fruits and seeds, though not immediately harmful, can affect the future regeneration of a species [16]. The part of the plants being harvested as product for the two species are the seeds, which ecologically may not cause immediate harm, is known to affect the future regeneration of the species [16]. The method employed as alternative harvesting method (or proposed sustainable method of harvesting) enabled collector to collect to maximum, but harvest such that seeds would remain to fully mature and freely fall on forest floor for regeneration of species that would replace old growth and dead trees and vines. This was evident in the results from the first harvesting seasons for both plant products using the alternative harvesting method (26.2 kg) being slightly lower than the traditional method (28.3 kg), and literally constant for the alternative harvesting method (26.5 kg) during the second season (Table 1). This trend indicates that a change in behavior pattern of harvesting by local community provides a win-win situation for both the plant species population and a benefit to local collectors. However, impact from traditional method of harvesting showed a decline in the harvesting of pods by cutting down the trees of Xylopia (Table 2) and vines of Griffonia (Table 2), thus confirming report by Juliani et al. [19] that destructive method of harvesting often leads to depletion of plant production.. This may be due to lack of knowledge on the importance of sustainability therein, as the plants naturally grow in the wild [19], or the idea of wild-harvested plants in relation to sustainability is being poorly understood in rural areas [21].

It is apparent to note the importance of sustainable collection of NTFP and the preservation of forest biodiversity with longer-term benefits of productivity and continuous income generation [27, 8, 39]. This was expressed in results realized from the alternative and improved method of harvesting that yielded similar collections during the two harvesting seasons for both plant species (Table 1), with very little impact observed during the second season for both plants (Table 2).

Conclusion

Traditional methods due to lack of knowledge of a better harvesting practice yields less and often leads to destruction and/or wastefulness of plant populations, which may cause population decline and loss overtime. Trained community members in the use of materials and tools that minimize damage to plant during harvesting were able to preserve the resource, at the same time obtain maximum yield. Changes in behavior pattern of local collectors towards sustainable harvesting techniques result in increased yields linked to biodiversity conservation. The study suggests that the training of people has huge impact on sustainable harvesting that leads to conservation and continuous yield production. Hence, sustainable collection of NTFP can ensure the preservation of forest biological diversity, with a longer-term benefit of productivity and continuous income. Results from both methods of collection were discussed with the collectors after the field study. There is need for training and awareness to the sustainable harvesting practices of NTFP.

Acknowledgement

I am very grateful to Cuttington University for making it possible to obtain a fellowship to study at Rutgers University in NJ/USA and to USAID-Excellence in Higher Education for Liberia Development (USAID/EHELD) that was managed by the Research Triangle Institute (RTI) for affording me this opportunity of learning; to Rutgers University for accepting me into the PhD graduate program in Plant Biology. Funds were also provided by Rutgers University relative to tuition and fees for part of my studies, to the New Jersey Agricultural Experiment Station and the New Use Agriculture and Natural Plant Products Program who each also provided additional resources in support of my research.

Conflict of Interest

The author(s) declare(s) that there is no conflict of interest.

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