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Rangeland restoration and monitoring for One Health in pastoral rangelands

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Executive summary

Restoration of degraded rangelands is an important component of rangeland management. Degraded rangelands provide little feed of poorer quality for livestock and wildlife, reducing pastoralist incomes and livelihoods, and making pastoralist producers more vulnerable to droughts and other shocks and environmental hazards. One of the best strategies for mitigating these problems is to restore the condition and productivity of rangelands. Restoration can make several contributions to larger One Health outcomes for livestock and people, depending on how and where it is conducted. Targeting restoration based on the rangeland management plans of local institutions could enhance success rates, increase between-treatment time intervals, and more significantly, enhance the livelihoods of pastoralists. Targeting is conducted through restoration planning conducted by local rangeland institutions under their larger rangeland management plans, based on local knowledge of pastoralists with complementary technical assistance and oversight by researchers and development practitioners. Action research trials on restoration options can be used to document quantitative restoration effects with precision, demonstrate these restoration effects unambiguously to pastoralist producers for knowledge and capacity building, and provide ground data for monitoring and evaluation of small-scale restoration, and large-scale grazing management through linkages to remote sensing methodologies.

Introduction

Restoration in pastoralist rangelands differs strongly from the practices used in ranching systems to enhance rangeland condition and productivity. Ranching generally applies more costly measures such as long periods of rest, reseeding, fertilization and fire management (Hunt et al. 2014) that would be more difficult for pastoralist producers and their institutions to finance or implement. In pastoral rangelands, the difficulty of controlling grazing of many herds with many livestock owners, the transaction costs this control requires, and enforcement, are significant constraints to restoration. Restoration in pastoral rangelands in East Africa typically employs labour-intensive options with variable success rates, such as thinning of encroaching shrubs (Negasa et al. 2014; Kimiti et al. 2017), trenches and other soil and water conservation measures (Desta et al. 2005), and communal grazing exclosure for specific animal types and seasons (Napier and Desta 2011; Aynekulu et al. 2017). Other options available include prescribed fire (LaMalfa et al. 2008) and brief resting of pastures (Sircely et al. in press), which can be added to the tools used by pastoralists to restore rangeland condition and productivity.

Planning of restoration is one component of rangeland management plans created by local rangeland institutions (Flintan and Cullis 2010, Robinson et al. 2020). Briefly, these rangeland management plans provide for large-scale grazing management, planning of non-rangeland land uses, and small-scale restoration based on the larger plan. Management planning provides the essential information needed for planning restoration, especially causes of rangeland degradation, management objectives of the local rangeland institution, and the views of pastoralist producers and their leadership on the likely effectiveness and feasibility of various restoration options. Restoration planning targets options or practices within the rangeland unit where they will be most effective and feasible, based on local knowledge and experience, with technical assistance from researchers and development practitioners. Since the perceived costs, benefits and risks of restoration options vary widely (Sircely et al. *in press*), action research trials are an effective means of demonstrating restoration techniques to producers, that also provide information useful in restoration planning and implementation, and monitoring and evaluation of successful local rangeland management.

By improving rangeland health at small scales, restoration can contribute to multiple One Health outcomes in pastoralist rangelands. Restoration is one component of improving large-scale rangeland health, serving in a supporting role for grazing planning and management. General improvement in rangeland health from restoration enhances feed availability and the health and productivity of livestock, along with ecosystem services such as carbon storage, infiltration of rainfall, and control of runoff and erosion. Restoration applied over sufficiently large areas can reduce grazing pressure on the larger rangeland, limiting degradation and preserving larger pasture areas. Greater access to pasture can serve to prevent potentially dangerous concentration of herds into small areas, which could pose higher risks of disease transmission and parasite exposure. Restoration planned with livestock health as an additional objective can further contribute to reduction or mitigation of direct threats to livestock health. Since pastoralists depend primarily on livestock, the multiple potential benefits of restoration to maintaining or improving livestock health can contribute both directly and indirectly to improving the health, nutrition, livelihoods and incomes of pastoralists.

Restoration planning

Restoration planning conducted by a local rangeland institution has the goal of targeting restoration options, or practices, within the rangeland unit for which this institution is responsible on behalf of their membership, users and residents of the rangeland unit. Reversing degradation in the most severely degraded portions of a rangeland must be addressed through active restoration efforts, since grazing management will not be sufficient for heavily degraded patches. If restoration is to contribute to broader One Health outcomes, its goals, techniques, planning and implementation can be targeted to locations where it will provide direct and indirect benefits to livestock health, in addition to restoring rangeland health. Here, the example of Arda Olla, a rangeland unit in southern Ethiopia, serves as an instructive case study of restoration planning. This information is drawn from a rangeland management planning exercise that was conducted in March 2021 (Sircely and Eba *in press*).

The local rangeland institution in Arda Olla has a hybrid leadership composed of *Garre* clan elders and local government (*kebele*) officers. It also has a similar hybrid clan-based/government (*kebele*) governance approach. The external and internal boundaries are those of four government-defined *kebeles*, while the management practice of seasonal grazing is largely traditional, and both traditional and government leaders make key management decisions together. Rules and by-laws of the institution are mostly traditional in origin, although repeat, flagrant violators may be referred to the *kebele* government. Arda Olla does not have government recognition of user rights, as Somali region has not yet enacted a process for government certification of user rights for communal lands. While Arda Olla cannot represent all pastoral rangelands, most of the rangeland management and One Health problems and solutions encountered in the area are common in pastoral rangelands of East Africa.

The most important causes of degradation in Arda Olla, which once had highland forests in its higher elevations and more large savanna trees, are tree cutting over recent decades, drought and heavy grazing. Some *kebeles* had to deal with higher tree-cutting, and areas with red soils and continuous heavy grazing have severe erosion and gullies, while droughts affect the entire rangeland unit. In response to these degradation causes, the management objectives agreed by the planning team from Arda Olla included: (1) to restore severely degraded localities with severe encroachment of shrubs and toxic plants, and major soil erosion including gullies; and (2) to improve the quantity and quality of forage and browse across the entire rangeland unit. The first management objective requires active restoration, while the second can be accomplished primarily through improved grazing management at the scale of the entire rangeland unit.

To address the management objective of healing bare ground and re-establishing a productive mix of grasses and woody browse in heavily degraded zones, a restoration plan was created for Arda Olla. Since the only restoration options Arda Olla had applied previously were trenches for soil and water conservation, pastoralists in the area would likely benefit from building their knowledge on how to successfully apply a broader variety of rangeland restoration techniques. Manual removal of encroaching toxic plants and shrubs was deemed the most feasible first step in restoring heavily degraded areas. Other restoration options proposed by the planning team included digging soil and water conservation structures, range reseeding and planting of fodder shrubs and trees in areas protected from grazing, and gully rehabilitation.

Each of these restoration options could potentially help restore rangeland condition and productivity, although their costs and benefits vary greatly, and depend largely on the details of their implementation, including sufficient post-restoration rest from grazing. Removal of encroaching shrubs and toxic forbs would help free grasses from competition, improving productivity and reducing deaths of livestock from consuming toxic plants, providing two clear benefits to One Health from restoration. Pastoralists often know how to remove each problematic species (though often this knowledge can be improved). However, removing this vegetation requires a fair amount of labour, and sometimes the treatment must be repeated after only a few years. Range reseeding and planting of fodder shrubs and trees are effective where grazing is tightly controlled for long periods of time, such as three years (Eba et al. 2014). However, reseeding is commonly unsuccessful (Sircely et al. in press, Svejcar et al. 2017) and range grass seed is often expensive (e.g. USD100 per hectare in Kenya) or unavailable (local multiplication would solve this supply problem). Digging trenches to conserve soil and water improves infiltration of rainfall into the soil, and reduces surface runoff and soil loss, while gully rehabilitation would slow the massive loss of soil and even loss of land itself (Desta et al. 2005). Trenches, and especially gully rehabilitation, involve high labour costs. In addition, their benefits to forage and browse productivity are indirect and can be weak unless coupled with reseeding and long-term grazing protections. Gully rehabilitation can, however, be conducted more efficiently by grazing large numbers of heavy-bodied livestock such as cattle or camels for a brief period of time (Butterfield et al. 2006) to break soil crusts and reduce the steepness of gully walls. Rehabilitating gullies would furthermore prevent them from blocking livestock movements, and reduce the loss of productive land.

Planning and targeting of rangeland restoration can be unclear. Where should restoration in the landscape begin? Where will restoration have the greatest effect? These questions, among others, often lack information from a quantitative scientific viewpoint. Local knowledge is often more accurate and useful than targeting approaches which require significant *a priori* assumptions that may or may not be valid. Further, using local objectives and plans to provide guidance on where and how restoration is implemented can improve effectiveness, efficiency and sustainability, especially if restoration is viewed as beneficial to pastoralist producers.

The likelihood that active restoration efforts will be successful and sustainable is increased by targeting each option to specific portions of the rangeland selected in the plan. The most feasible first step was removal of shrubs and toxic forbs, which was selected for an action research trial to assess the effectiveness of this restoration option (see 'Action research trials' below). The aim was to restore heavily degraded areas on red soils (nitisols) in valuable dry season grazing areas that pastoralists rely on (Oba 2012) especially when forage is scarce, milk production is low and the risk of livestock mortality is higher. These highly degraded areas also experience severe soil erosion, including gully formation. Since grazing will need to be controlled for three months following shrub and toxic forb removal, the locations must fall where this is feasible, another important reason for targeting according to the management plan. Targeting under the management plan also allows restoration to be implemented in areas that will not be cropped soon, as this would eliminate the benefits of restoration.

Restoration techniques are best targeted mostly through local knowledge to areas where they are likely to be most beneficial, as complemented by technical assistance and oversight. In Arda Olla, local targeting of removal of shrubs and toxic forbs will be located in specific areas in three of the four *kebeles* within the rangeland unit. According to the planning team, this option will be applied in areas with high density of problematic vegetation, with high potential to regenerate productive forage and browse (i.e. not persistently or stably degraded), in areas with red soils outside of the hilly highland portion of the rangeland. Since manual removal of problematic vegetation and other active restoration techniques are often costly in terms of labour, low-cost techniques that could be considered include resting for the briefest effective period feasible (Ash et al. 2011; Robinson et al. 2020; Sircely et al. *in press*), or use of very heavy, very brief grazing (Butterfield et al. 2006) to, for example, reduce woody and weedy species and to favour recovery of grasses.

Removing encroaching, non-palatable and toxic plants will release grasses from competition. As a result, grass cover and productivity will increase, soil erosion will be reduced, and the effective area of pasture available to species more sensitive to these toxic forbs, goats and sheep, will be increased by a small margin. Currently, Arda Olla plans to restore approximately 40 hectares of land per year in this manner. However, even under-estimating that 5% of the rangeland requires treatment currently, at this rate it would take over 15 years to apply this approach throughout the rangeland unit. Moreover, many of these areas would also need to be re-treated after a few years. One strategy for accelerating rangeland restoration on a large scale is to improve the efficiency of active restoration methods, such as by applying herbicide to the stumps of cut shrubs. Fire management would be much more efficient in clearing large areas of encroached rangelands (LaMalfa et al. 2008), and would likely destroy many of the seeds of toxic forbs. Often, though, pastoralists are reluctant to burn what little grass they have available, requiring a strategy for successfully introducing prescribed fire. Still, larger-scale strategies are clearly needed to target and reinforce active restoration, strategies provided for in the larger rangeland management plan, especially grazing management at the scale of the entire rangeland unit of Arda Olla.

Removal of toxic forbs is directly linked to livestock health, especially for sheep and goats, which are more sensitive to this toxic species. In addition, this restoration approach would reduce the area prone to high populations of ticks, tsetse flies and worms (soil-transmitted helminths). Each of these threats to livestock health have been linked to expansion of woody cover and its effect of reducing soil and near-surface temperatures. It would reduce populations of ticks (Negasa et al. 2014) could potentially reduce populations of the tsetse fly vector that transmits trypanosomiasis (Egeru et al. 2020) and which was historically absent from the area, and could potentially also reduce the persistence of eggs of several worm species in soils (Brooker et al. 2006).

Action research trials

Action research trials have several functions in improving rangeland restoration. From the perspective of rangeland residents and users, trials provide a systematic demonstration of restoration effects. From the perspective of monitoring and evaluation specialists and researchers, trials provide the research integrity to reveal precise restoration effects, enabling documentation of clear evidence of restoration benefits. In addition, the experimental control areas serve as ground monitoring locations that can be linked to remote sensing.

Given the considerations described above (see 'Restoration planning') regarding restoration options, the planning team selected removal of encroaching shrubs and toxic forbs for ongoing action research restoration trials managed by the Arda Olla rangeland institution, with minimal technical assistance. The overall process of action research trial development follows an approach previously applied in pastoralist rangelands in Kenya and the Ethiopian highlands (Sircely et al. 2020). Briefly, the action research trial development process comprises local engagement, creation of an experimental protocol, vetting of the protocol with local institutions (in this case, Arda Olla) and implementing the action research trial. The result is precise quantification of restoration effects (Sircely et al. *in press*).

The trial on removal of encroaching shrubs and toxic forbs in Arda Olla was specifically designed to restore heavily degraded areas on red soils (nitisols) in valuable dry season grazing areas that pastoralists rely on during the dry season. The trial protocol (Appendix A) calls for multiple blocked experimental areas where shrubs and toxic forbs are removed (treatment areas), as compared with adjacent areas managed as usual (controls). The trial will be conducted in three *kebeles* within Arda Olla rangeland unit, with two research areas—one treatment and one control—in each *kebele*. Each treatment area of 2 ha (250 x 80 m) will have three LandPKS (Land-Potential Knowledge System) research plots (Riginos et al. 2011). Similarly, each control area will have three LandPKS plots. The total design will have nine treatment plots (blocked replicates) and nine controls. Analysis of covariance will be used to analyse the response of indicator value outcomes as a function of baseline indicator values as a continuous predictor, and treatment as a categorical predictor. Results of the trial will be assessed using several indicators of general rangeland health (condition and suitability for livestock production): cover and height of useful forage and browse species, cover and height of encroaching species (mostly woody shrubs), and cover of bare ground. Two additional indicators will be used to link rangeland health improvement to livestock health: cover of toxic forbs, and densities of ticks, which have been linked to shrub encroachment in the area (Negasa et al. 2014). The perceptions of pastoralist producers will also be used as indicators of general rangeland health and its links to livestock health.

Identification of treatment and control areas for the trial will be conducted jointly. General treatment areas will be identified by Arda Olla: areas with high density of problematic vegetation, with high potential to regenerate productive forage and browse (i.e. not persistently or stably degraded); areas with red soils outside of the hilly highland portion of the rangeland; in three of the four *kebeles* of Arda Olla. Targeting to degraded though potentially recoverable areas is a significant influence of local knowledge that would be difficult to replicate without a multi-year scientific effort, as is the general locations in terms of the feasibility of controlling grazing during the post-restoration period of three months. The precise treatment and control areas will be identified within the pre-selected general area by researchers and partners. However, this final decision will be made together with Arda Olla. Baseline measurements will be taken before the restoration treatment is applied.

Most problematic woody species or individual plants and branches of high browse quality in areas of high density will be removed by cutting at 15 cm height. Woody encroaching species that resprout vigorously after cutting will be cut at 50 cm height, with stump de-barking, or cut at ground level and kerosene applied to the stump. Problematic herbaceous species, especially those toxic to livestock, will be removed by uprooting the entire plant. After removal of problematic vegetation (during the long dry season), treatment areas will be rested from grazing for three months in the following short rainy season. Outcome measurements will be taken at a similar point in the season as baseline measurements to ensure comparability and avoid effects of seasonal variability.

Rangeland monitoring

The specific design of the restoration action research trial provides two significant additional advantages: providing ground monitoring data, and linking this data in space and time to remote sensing indicators of rangeland condition. Both ground monitoring data and remote sensing can be used for monitoring and evaluation of, respectively, the restoration trial at small scales (Sircely et al. *in press*) and large-scale rangeland management (Sircely et al. 2019; Robinson et al. 2021) conducted by local rangeland institutions such as Arda Olla, covering entire rangeland units (100s–1,000s of km^2; e.g. ~200 km^2 for Arda Olla). Two absolutely essential aspects of the spatial trial design make it suitable for monitoring and evaluation of both small-scale restoration and large-scale rangeland management—there are multiple research locations within the rangeland unit where trials are conducted, and each location has multiple treatment and control plots. The variability in rangeland condition and response to restoration captured through this approach enables the effective and appropriate use of statistics to demonstrate and document improvement in rangeland condition with precision.

Remote sensing has the potential to detect meaningful changes in rangeland condition in response to large-scale changes in rangeland management (Sircely et al. 2019; Robinson et al. 2021). However, the accuracy of remote sensing methods in rangelands is highly variable, motivating the use of ground monitoring data for evaluating the accuracy of remote sensing products (e.g. Guerschman and Hill 2018), as well as to build more accurate models better able to represent rangeland condition on the ground with fidelity. Both treatment and control areas in the restoration trial can be directly linked to remote sensing of trends in rangeland condition (Robinson et al. 2021) at high resolution (e.g. 10 x 10 m), strengthening confidence in the local application of remote sensing methods for monitoring and evaluation of rangeland management at the larger scale of the entire rangeland unit. Some remote sensing indicators are easier than others to ground-truth and to quantitatively measure changes over time, with bare ground being among the most robust as it has higher statistical power, and can be quantified with high accuracy using large-scale measurements such as those in the trial, LandPKS plots (Riginos et al. 2011). The large size of these plots (60 x 60 m) integrate over a greater range of the substantial variability in rangeland vegetation and/or soil condition at fine scales (e.g. < 10 m).

Conclusion

In pastoral rangelands, restoration will be most effective when targeted according to a large-scale management plan that provides for grazing management and planning of non-rangeland land uses. Targeting under a locally credible management plan for a local rangeland institution can improve the short-term success of restoration, with control of grazing enabled by grazing plans. Effective targeting can also improve the long-term success and sustainability of benefits from restoration, by ensuring that restored locations are not converted to non-rangeland land uses (which would eliminate any benefits of restoration). Targeting of restoration options and specific locations should first and foremost be based on local knowledge and the larger rangeland management plan for a specific rangeland unit such as Arda Olla. Local knowledge with technical assistance and oversight from researchers and development practitioners (government and civil society) makes for a potent combination of complementary local versus global knowledge and experience (Sircely 2019; Sircely et al. 2020).

Restoration of rangeland health can contribute to larger One Health outcomes through multiple mechanisms. First, general improvement in rangeland health from restoration will improve feed availability, and the health and productivity of livestock, along with rangeland ecosystem service delivery. If conducted over large scales, restoration can help alleviate grazing pressure on pastures outside the restored area, reducing landscape degradation risk, and supporting preservation of larger pasture areas that enable fine-scale separation of herds to prevent disease transmission and limit parasite loads. Second, restoration that is well-planned with livestock health as an explicit objective can also reduce or mitigate direct threats to livestock health, especially diseases and parasites, and as seen in Arda Olla, toxic invasive species. Each of these benefits to maintaining or improving livestock health contribute to improving the health, nutrition, livelihoods and incomes of pastoralist producers, who depend primarily on livestock.

As more action research trials are conducted, quantification of restoration effects of various restoration options will become clearer and emerge from their currently often vague status. Explicit consideration of livestock health and other One Health benefits from restoration, such as reduced tick populations in Arda Olla, will enable the design and targeting of 'win-win' restoration strategies for multiple One Health outcomes. The design of these trials moreover inspires greater confidence in the accuracy of remote sensing estimation of changes in rangeland condition in response to changes in management by local rangeland institutions (such as Arda Olla) at the scales of entire rangeland units.

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Appendices

Appendix A. Protocol for removal of encroaching shrubs and toxic forbs in Arda Olla Rangeland Unit

Restoration action research protocol:

Removal of toxic forbs and encroaching shrubs, Arda Olla Rangeland Unit

Introduction

Available land for grazing in Arda Olla has shown a decreasing trend which is due to decline in the quality of rangelands and rainfall shortages. This deterioration of rangeland is due to poor rangeland management and natural resources governance practices, increased human, and livestock population pressure. In the rangeland unit, the invasion of forbs toxic especially to goats and sheep and encroaching shrub species are linked with sheet and gully erosion, ultimately resulting in the loss of vegetation cover and even land itself. Shrub encroachment has also been linked to increased populations of ticks, tsetse flies, and worms that infect livestock. For these problems concerned stakeholders, need effective response measures and in an organized manner to tackle the severity of the problem.

Objectives: Improve the grass/browse quantity and quality; heal bare ground to reduce erosion and improve the grass growth and browse plants; control the expansion of toxic forbs.

Hypothesis: Removing the toxic forbs and encroaching shrubs, with post-removal resting, will significantly improve recovery of vegetation useful to livestock production, and will decrease tick populations.

Options to compare: Removed of problematic vegetation (toxic and encroacher species) and resting versus without removal of problematic vegetation and resting.

Contexts to compare: Kebeles, cover and biomass of problematic vegetation removed, elevation.

Responses to measure: Cover of toxic plants, cover of encroaching shrub species, cover of plant bases, cover of bare ground, tick populations, and community perception.

Study units: In each of 3 of the 4 kebeles in Arda Olla, 1 research location will be created, with a treatment area of 2 ha (250 x 80 m) and a control area of 2 ha (250 x 80 m). Each of the 3 research locations will have 3 Land PKS plots (60 x 60 m) in the treatment area, and 3 Land PKS plots in the control area, for a total of 9 treatment plots, and 9 control plots.

Steps to follow the for-research action trials.

- Discuss and identifying areas for the restoration action research trail with communities. The community will identify the general areas of toxic and encroacher plants infested that to be representative of the rangeland unit having similar problems, in dry season grazing areas affected by degradation but with potential for strong recovery with treatment.
- Delineation of restoration action research trial areas with communities. The community demarcates the areas identified to be for action research trails among identified areas and bush-fenced with local materials.
- Arrangement how the action trail areas to be kept. The community discuss and decided how the area of action trails will be protected from the interferences of livestock.
- Collect baseline data from the action research trial areas. The baseline data are collected from all research locations by ILRI, and the community and partners are trained in taking these measurements along the way.
- Application of restoration through removal of problematic vegetation.
- After restoration treatment, the area will be rested for 3 months in the following rainy season.
- Collect outcome data from the action research trial areas. This at the end of the action research that data collected from same control and treatment plots.
- Analyze data and report back to the rangeland unit, solicit community perception of the restoration treatment, and assess use of this information in future restoration planning and implementation.

Roles of institutions and individuals:

Roles of user group members: Communities will select the general site, protect the area during resting, and coordinate and implement all activities related the removal/cutting of the plants. Woreda experts also involved in selection of sites, oversight during resting, and collection of action research data.

Partner/VSF-S: Involved in facilitating the community, site selection, data collection and oversight the during resting time of the cleared area.

ILRI: Lead the implementation of research trials, prepare the protocol, facilitate the discussion within the community to select the sites based on their context, lead training of partners and the community on data collection, prepare reports based on the results, follow up on the sites during the research period, provide the budget for removal of plants and other activities, facilitate the rangeland unit to prepare the by-laws for enforcement of the planned options.

Actions for removal unwanted plants will be:

Unwanted plants are encroaching shrubs, weeds, and toxic forbs. Hence, identification of the plant types, such as encroaching plants (and the growth form or life form) will be carried out by community according to local knowledge.

Within each treatment at all research locations the unwanted plants will be removed. Most species of encroaching shrubs will be removed by cutting at 0.15 m. Some smaller species and individuals will be removed by up-rooting the entire plant where feasible. The removal methods are subject to change depending on the encroacher species, such as cutting at 0.5 m height with stump de-barking, and cutting at ground level with application of kerosene on the stump. If there is an excessively high and problematic density of useful plant species, these will be thinned by roughly 50%, depending on the preference of community. Problematic non-woody plants including toxic forbs will be removed by up-rooting the entire plant. The treatment areas will be rested from grazing for 3 months in the following rainy season. If the vegetation successfully recovered application of grazing management in one year will be done and no further restoration options may need to be applied. If this treatment is not successful it will be followed by another treatment like reseeding or soil and water conservation structures.

Table 1. Seasonal schedule for removal of problematic vegetation.

Sr.no	Season	Plant growth form	Cutting/removal types	Remark
1	September to October	Woody plants	Cutting at 0.15 m height; Thinning at 50% if density of valuable plants is high	Cutting methods subjected to change depending on types of species
2	September to October	Non-woody plants	Uprooting from the ground	
3	January-March and July	Woody plants	Cutting at 0.15 m height; Thinning at 50% if density of valuable plants is high	Cutting methods subjected to change depending on types of species
4	January-March and July	Non-woody plants	Uprooting from the ground	