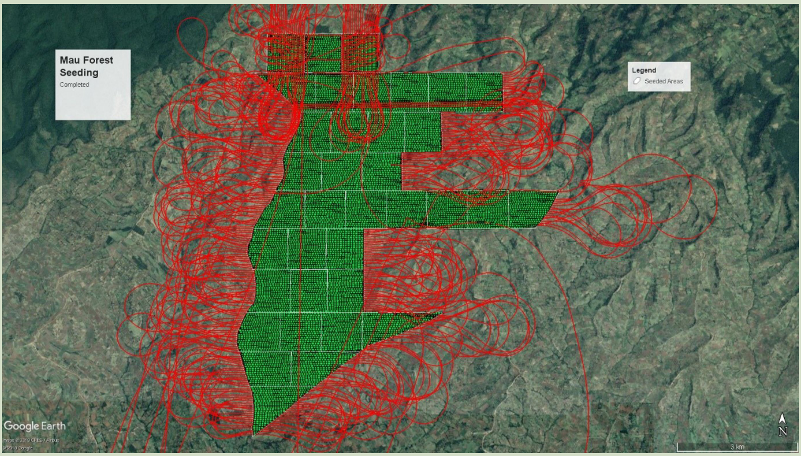
KENYA FORESTRY RESEARCH INSTITUTE

PROTOCOL FOR AERIAL SEEDING OF DEGRADED FORESTS AND OTHER LANDSCAPES IN KENYA



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PROTOCOL FOR AERIAL SEEDING OF DEGRADED FORESTS AND OTHER LANDSCAPES IN KENYA

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Captions for cover photographs:
Top left: Aircraft airborne broadcasting seeds
Top right: Verifying seeds on the ground
Bottom: Aerial seeded area (green colour) overlying the flight paths, covering 3,600 ha

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PREFACE

Like many other African countries, forest and land degradation is a serious problem in Kenya. Yet these landscapes remain a critical resource to the advancement of human populations and therefore their restoration is paramount towards improving human livelihoods, long-term food security, biodiversity conservation and climate stability. Nonetheless, some of these landscapes present difficult and challenging problems in rehabilitation. While some are small patches, majority are large contiguous lands often not easily accessible due to the difficult rugged terrain. For the small patches, good progress in rehabilitation has been made using conventional methods of raising and planting seedlings. However, for expansive degraded areas, employing conventional methods would be expensive and likely to take many years. How can such areas be brought back promptly into tree production? Fortunately, aerial seeding technology is seemingly an easier method that is also suited for reforesting large inaccessible and degraded sites, rapidly and at a relatively low cost. The technology also overcomes challenges associated with poor detection of target sites as well as other hazards such as wildlife. Aerial seeding technology is an old practice and is well documented globally, but is relatively new in Kenya as in many other developing countries.

In November 2019, the technology was deployed over degraded sections of Maasai Mau Forest and aided in seeding 3,600 ha, broadcasting slightly over 3,600 kg of indigenous seeds in just three days. While the technology was geared towards the realization of the national strategy to achieve and maintain 10% tree cover by 2022, it was conducted on pilot-basis, aiming at providing research and learning opportunity through which to develop and/or localise aerial seeding standards and develop protocols to guide application of the technology. The exercise provided an opportunity for developing much needed information on the potentialities of airplane seeding as a means of successfully regenerating degraded forestlands.

The exercise also yielded valuable insights regarding the procedures to be followed to obtain the best results from aerial seeding method of reforestation.

This protocol has been compiled out of aerial seeding piloting experiences and insights, and documents the coordination and technical activities that are required for successful implementation of aerial seeding exercise. It is my hope that this protocol will be useful in guiding additional aerial seeding exercises in order to fast-track rehabilitation of degraded forestlands and landscapes in Kenya.

Sammy C. Letema (PhD)
Chairman, KEFRI Board of Directors

ACKNOWLEDGEMENT

Preparation of this protocol has been a success courtesy of the concerted effort of various actors; both within Kenya Forestry Research Institute (KEFRI) and outside. I would like to acknowledge the roles and contributions of everyone individually and collectively.

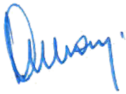
My sincere gratitude is to the leadership in the Ministry of Environment and Forestry, for having recommended the piloting of aerial technology and demonstrating confidence in KEFRI to coordinate the exercise. Special thanks goes to the Cabinet Secretary Hon. Keriako Tobiko, who has steered much of the landscape restoration and tree planting efforts in the country.

My appreciation also goes to partner organization including Kenya Forest Service (KFS), Kenya Water Towers Agency (KWTA), Department of Resource Surveys and Remote Sensing (DRSRS), and Kenya Meteorological Department (KMD). I particularly acknowledge the services rendered by their staff who had been nominated to provide technical support. I wish to also thank the owner of Farmland Aviation for providing the aerial services at a very critical moment in Kenya's forestry sector. The role played by the County Commissioner of Narok during the exercise is also acknowledged.

Within KEFRI, I would like to acknowledge the leadership role played by the Senior Deputy Director- Research & Development throughout the planning and execution of the aerial seeding exercise. Her constant follow-up ensured the work progressed well despite the numerous challenges.

I am also much indebted to the members of the Technical Team that spearheaded the exercise of piloting aerial seeding in rehabilitation of Maasai Mau Forest. Indeed, the lessons from that exercise have largely been applied in compiling this protocol.

To all those who in one way or another participated in the realization of this protocol, I say thank you. I wish to reiterate the Institute's commitment in demonstrating and operationally deploying pioneering research, innovations and technologies in our concerted efforts to provide solutions to our country's problem.



Joshua K. Cheboiwo (PhD)
Director, Kenya Forestry Research Institute

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1.0 INTRODUCTION

Aerial seeding technology is an old practice and is well documented at global level, but is relatively new in Kenya. The technology is already regarded as a practical reforestation technique with success in the United States of America, Canada, Australia, Russia, India and New Zealand. Although uptake of the technology is low in developing countries, majority of these countries are re-considering taking up aerial seeding since the traditional method of raising and planting seedlings is already overwhelmed relative to the extent of land in dire need of restoration. Application of aerial seeding by developing countries will also benefit from past experiences drawn from countries that pioneered and implemented the technology in forestry. The cost effectiveness of applying aerial seeding technology on large scale restoration programs makes it a preferable option.

Like many other African countries, forest and land degradation is a serious problem in Kenya and forest restoration is therefore a high priority agenda for the Government. Restoration opportunities have been identified either over large contiguous areas or in some cases, over small areas. With respect to the small areas, good progress in restoration has been made using traditional method of raising and planting seedlings. For large areas, planting seedlings is a drop-in-the-ocean relative to the expansiveness of areas requiring restoration. Much of these large areas are often not accessible due to rugged terrain that has only been opened-up by non-motorable roads, therefore remaining a key barrier to achieving restoration targets solely based on traditional methods. Restoring these areas through traditional methods will be difficult and likely to take many years coupled with heavy financing. Aerial seeding is therefore well suited for reforesting large sites that are disturbed and inaccessible due to rough terrain, rapidly and at a relatively low cost. The technology also circumvents challenges associated with poor detection of target sites, reduced access to the sites as well as other hazards such as wildlife. In Kenya's forestry sector, application of aerial seeding technology is projected to play an increasingly important role given the need to fast-track rehabilitation/restoration of degraded forestlands.

This protocol has been produced with the aim of supporting Kenya's forestry sector in its endeavour to apply aerial seeding technology to meet the countrys restoration targets. The protocol provides key technical guidelines for successful planning and execution of aerial seeding mission over targeted landscape(s).

1.1 Objectives of the protocol

The objective of this protocol is to provide a coordinated, effective, and tractable way of guiding aerial seeding geared towards rehabilitation of degraded forestlands and landscapes in Kenya.

1.2 How to use the protocol

Chapter two (2) elaborates the technical procedures of key preparatory activities required for rolling-out aerial seeding exercise, including approval, planning and coordination. Chapter three (3) is the main framework of the protocol, describing details of activities that are implemented, culminating to a successful aerial seeding operation. These activities have not necessarily been organized sequentially, but compiled as compendium of the requisite actions, although outputs of some lower level activities feed into higher level activities. The person coordinating the aerial seeding exercise ought to ensure that the activities are implemented and each deliverable channelled to the right action node. It is hoped that once the technical team is constituted, members will work together to deliver the set of activities as required.

2.0 TECHNICAL PROCEDURES GUIDING THE PREPARATORY ACTIVITIES

This chapter elaborates the technical procedures of key preparatory activities required to roll-out aerial seeding exercise. The activities form the foundation of successfully planning and coordinating the exercise. Since aerial seeding will mainly be undertaken from public funds and mainly over public land, it is critical that the exercise be officially approved, planned and coordinated by relevant authorities.

2.1 Seeking approval for the aerial seeding project

Aerial seeding project targeting public lands and financed by public funds ought to be advanced only after the necessary approval has been granted. Whether it is for purpose of ensuring prudent use of public fund or to ensure that aerial seeding is part and parcel of the broader forest rehabilitation program, it would be necessary to seek relevant approval. For the case of aerial seeding of reclaimed section of Maasai Mau Forest, approval was granted by the Ministry of Environment and Forestry as well as by the KEFRI Board of Directors. Seeking approval shuld be by the chief executive officer of the project coordinating organization.

2.2 Constituting a technical team to coordinate the aerial seeding project

As aerial seeding is usually part of a broader forest rehabilitation program, its planning and execution entails concerted effort from various experts and organizations. A multi-disciplinary team of experts will provide various skills as follows:

- Mapping skills for purpose of delineation of degraded forest areas with potential for aerial seeding;
- Skills in identification of plants, plant assemblage and plant communities;
- Soil classification and / or fertility assessment skills;
- Expertise in tree-seeds characteristics and germination;

- Skills in community sensitization and /or mobilization;
- Procurement, contracting process, transport logistics;
- Expertise in flight operations; and
- Weather information and seasonal projection.

The technical team not only draws membership from various specialist offices/staff, but also from lead institutions in environmental sector. In piloting the aerial seeding in MMF in Kenya, experts were drawn from; Kenya Forestry Research Institute (KEFRI), Kenya Forest Service (KFS), Kenya Water Towers Agency (KWTA), Department of Resource Surveys and Remote Sensing (DRSRS), and Kenya Meteorological Department (KMD). Membership to the technical team is through appointment by the respective chief executive officer. Work of the technical team should be guided by clear terms of reference (sample ToR in Annex 1). Deliberations of the team are through formal meetings, (both physical and virtual) during which proceedings are recorded.

2.3 Visioning the sequence of key activities for successful aerial seeding mission

Once constituted, the technical team should meet to discuss the proposed aerial seeding mission to vision the key activities and logical flow that ought to be carried out to ensure successful mission. Result of such visioning is an Action Plan that focus the team to the goal as well as Budget Estimate for the work. Visioning exercise is meant to identify the key tasks to be implemented, and to ensure that all members of the team have a common understanding of the project. Based on experience of aerial seeding of reclaimed section of MMF, the list of critical activities include the need for:

1. Clarifying and defining objectives of the proposed aerial seeding exercise.
2. Preliminary mapping based on satellite images to isolate aerial seeding sites.

3. Ground verification of isolated sites; determination of the range of suitable species; identifying sites for hand broadcasting.
4. Sensitizing local communities on the planned aerial seeding.
5. Confirming availability and appropriateness of technical facilities critical for aerial seeding operation vis-à-vis the target landscape: the location of airstrip close to target seeding area; and storage facility close to the airstrip for storing seeds and other key items.
6. Procurement process including; procurement and contracting of aerial service provider(s), and purchasing / ordering of tree seeds.
7. Making preparation for required materials, and ascertaining the logistical readiness for the exercise: e.g., arrangement for seed dispatch from supplier; arrangement for seed transport to field; timely availability of the required casual labourers, tarpaulin, gunny bags, weight balance, and standby pick-up or tractor.
8. Ensuring readiness of seed for aerial seeding, entailing obtaining seed from various suppliers.
9. Getting further information with respect to alternative ways of handling variable sizes of seed without compromising uniformity of aerial seeding; clarity on aspects of desired seeding rate and spacing of expected seedlings; and the techniques for pre-treatment of seeds.
10. On- ground assessment of seed-drops, during the actual aerial seeding operation.

Box 1: Fieldwork preparations

- In view of the limited financial resources available to facilitate field work, it is advisable to deliver several objectives whenever field work is conducted.
- In order to ensure success of the field work and maintenance of security, it is advisable to liaise with office of the respective administrative offices in the field such as Office of the County Commissioner.
- It is important to prepare as early as possible for financial resourcces for field facilitation, fuel, and payment of labour.
- A strong motor-vehicle is critical in case of rough terrain, inaccessibility in some areas due to bad roads or no roads at all, sections of road with very loose slippery soil, or muddy roads.

3.0 PROTOCOL FOR EXECUTING ACTIVITIES TOWARDS SUCCESSFUL AERIAL SEEDING EXERCISE

3.1 Delineation of degraded area(s) for targeted aerial seeding in any selected forest ecosystem or landscape

Within the degraded forestland or landscape earmarked for rehabilitation/ restoration, it is critical to delineate the specific area(s) over which aerial seeding will be conducted. The output of this tasks is a final map of contiguous areas that are degraded and respective statistics (size in ha). This map is important for purpose of guiding the planning of flight paths as well as costing the job by the aerial service provider. The workflow to produce the final map will include the following:

1. A preliminary map is first produced using freely available satellite images. The optical Sentinel 2B is freely available and with relatively good spatial resolution (about 10 m). Images for this work should preferably be acquired during the window period when aerial seeding operation would be conducted (minus or plus a week).
2. Where the area targeted for aerial seeding has high variability of ground surface, such conditions may project differentiated effect on seed germination. Therefore, there is need for discriminating varied ground surfaces, for example, cropped-land or virgin grass patches from other land cover types. Such conditions would require use of very high spatial resolution images (for example image acquired using unmanned aerial vehicle).
3. Skilled remote sensing expertise is required in processing the images and generating the intended products. The technical team should have personnel with such expertise including access to remote sensing software packages and adequate time allocated for the task. The expert should endeavour to carry out desktop work and produce a preliminary map.

4. For purpose of ground verification of degraded sites delineated in the preliminary map and ascertaining the areas earmarked for aerial seeding, the following sub-tasks are required.
    - Develop a protocol (and planned route) for ground verification, including the preliminary map of degraded areas overlaid with nearest towns/villages and sites to visit for confirmation as well as data/information capture form.
    - Feed the coordinates of sites intended to be visited into GPS to be used to guide the mission.
    - Conduct the field work and record observations.
5. During ground verification (or pre-seeding site visit), capture GPS coordinates for sub-sites selected for separate experiments, including: site(s) for hand-broadcast of seeds; site(s) for seedlings planting; sites for aerial seeding; and control sites reserved for natural regeneration.
6. Following ground verification, a refined final map is produced as the output, clearly delineating the sites targeted for aerial seeding and preferably gridded into blocks of 100 ha and which should be labelled with numbers.
7. The experimental sub-sites selected for separate experiments should also be drawn as representative polygons and overlaid on the refined map (see sample map in Annex 2).

3.2 Determination of ecologically suitable tree species for re-seeding and available seed stocks

For any aerial seeding operation, it is important to clarify whether the aim is full restoration or simply rehabilitation. "Rehabilitation" means the reparation of ecosystem processes, services, and productivity but it does not mean to restore the ecosystem to its pre-existing condition. Rehabilitation projects are relatively easier to accomplish but there is need to match the site with vegetation species for ecological resilience.

Selection of plant species for seeding or planting is primarily based on 'available materials', but being ecologically suitable for the specific rehabilitation sites. The following sub-tasks are required:

- Literature review to understand range of woody vegetation species in each of the forests selected for rehabilitation. As an output, a draft list of woody vegetation species will be prepared for the areas targeted for rehabilitation.
- Develop protocol (and planned route) for ground verification of the range of woody vegetation species endemic to the areas targeted for rehabilitation as well as data/information capture form.
- Conduct the field work and record observations.

1. Based on the list of ecologically suitable wood vegetation species, confirm availability of certified seeds e.g. at Kenya Forestry Seed Centre of KEFRI, ensuring the readiness of seeds for aerial seeding. The available stock should officially be communicated.

2. Appraise the status and characteristics of available seeds, including whether or not possible pre-treatments are prescribed. A seed scientist or expert should conduct the appraisal and document the recommendations. It is important that prescribed pre-treatments of the seed be effected. This calls for ample time to be allocated for preparation of aerial seeding operation so that such preparations be done well in advance.

3. Determination of the optimum seeding rate is imperative, especially in view of the seed stock available to cover the area targeted for rehabilitation. Seeding rate should also be evaluated while catering for expected seed losses and amount of seed to deploy based on stock available, probability for germination, seedlings expected per hectare, and the target area delineated for seeding. This evaluation should be carried out by a seed scientist or expert who then documents the recommendations.

4. Based on the evaluation, a buying order should be officially placed. Order for seeds should officially be confirmed by tree seed supplier.

5. In order to guarantee uniform seeding rate for a given broadcast trip, the seeds should be of same diameter range species. This way, the seeds will interact with the aircraft's hopper uniformly. Seeds thus ideally should be of the same species or species that bear seeds of similar physical characteristics in terms of size. Seed balling has been suggested as having merit to achieve such uniformity albeit at an extra cost. Seed balls also protect the seed once on the ground from being eaten by rats and birds such as guinea fowl, until such a time that they are ready to germinate. Additionally, the seed balls would not be blown around by the wind resulting in a more uniform and accurate application. However, decision for seed-balling should be arrived at bearing in mind the cost implication in terms of balling the seeds, the increased volume and weight of seed balls and therefore additional flights that would be added to overall aerial seeding cost.

3.3 Sensitization of stakeholders and local communities

Effective sensitization of local administration and communities is important in order to avert any possible suspicions and/or agitations among stakeholders who would otherwise not understand what the aircraft would be doing flying over their neighbourhood. Similarly, seeking feedback and consensus from among the forestry practitioners and scientists on the strategy as well as about technical information of aerial seeding would also contribute to shaping the future of aerial seeding of degraded forestlands and landscapes.

- Among forestry practitioners, stakeholders and scientists, feedback and broader consensus about aerial seeding projected over a certain degraded forestland or landscape could be sought through workshops or scientific colloquium.
- Prior to sensitization of institutions on the ground as well as local communities, it is critical to inquire about the grass-root structures of the forest adjacent communities as well as government administration. The output will be a draft list of contacts and location of forest adjacent communities and key government administration that must be sensitized in readiness for the aerial seeding exercise.

  Other important sub-tasks include:

  • Develop a planned route for visiting identified informants. The output will be a planned route for visiting key informants.
  • During field work, sensitize the stakeholders. The output will be a documentation of the sensitization work.

- Sensitization of local administration and institutions affiliated with the degraded forestland or landscape targeted for aerial seeding, is ideally achieved by conducting one-on-one meeting with or courtesy call to relevant institutions. It is important for these institutions to appreciate the relevance of aerial seeding within the broader goal of realizing the national or multi-lateral forestry targets.

- The local community residing in or at the periphery of the degraded forestland or landscape targeted for aerial seeding can be sensitized through assistance of local administration such as the area Chief. The area Chief is front-line government administrator in direct contact with citizens at the grassroot and interacts with them on day-to-day basis. Through the Chief, it is possible to organize barazas (community meetings) and thus reach out to a large number of residents especially those who have stake in the target seeding area as well as leaders of community forest association (CFA) and water resource users associations (WRUAS).

3.4 Initiating procurement of service provider(s) for aerial seeding of specific delineated degraded site(s)

In collaboration with the relevant Supply Chain Management Division, it is necessary to develop a realistic specification for aerial seeding which will be used to procure and contract a suitable firm to provide aerial seeding services. The specification should have clear criteria for assessing quality of service to be delivered. A sample specifications for services of aerial seeding of degraded forests and other landscapes in Kenya is shown in Annex 3.

For purpose of circulating the specifications to potential service providers, the client is obligated to share key information (Annex 4) to enable the service provider evaluate the work and be in a position to bid for contract. The information to be shared include:

- Map of site(s) targeted for aerial seeding should be provided by the client. The map can either be in ESRI Shapefile or Google Earth format, or whichever digital format is available.
- Pre-seeding flight would particularly be crucial for the operator. The client (or contracting organization) should also assess the technical capability of the aerial seeding provider.

The main technical scope of assessing the capability of aerial service provider encompasses aspects such as:

I. The tonnage (or payload) of the aircraft,
II. Speed of executing the work, for example, in terms of hectares per hour,
III. Requirements by the potential service provide to allow making proper planning for executing the aerial seeding exercise in any targeted forestland or landscape,
IV. Suggestions for the key specifications by the client that would be measurable or observable, for purpose of quality assurance of aerial seeding over the targeted forestland or landscape,
V. For logistics during actual aerial seeding operations, clarifications about the need (or not) of manual labourers (say for offloading or loading, standby pickup or tractor, etc.), and to shoulder these logistical requirements, (whether the client or contractor)?
VI. The potential service provider should provide details regarding the location of airstrip nearest to the degraded forestland or landscape targeted for aerial seeding; clarification on whose responsibility to apply for access to such airstrip; and availability of storage facility and security for seeds.

Procurement of aerial seeding service provider should be settled as early as possible to enable timely service provision hence avoid disappointment.

The operational elements of aircraft used for seeding or spraying, this is reserved as skills of the aircraft operator and therefore not covered by this protocol. However, a number of aspects that would assure quality of the service are expected based on the professionalism of the service provider and the aircraft operator. The key aspects for quality asuarance are as follows:

- It is critical to clean the hopper after completing each seeding or spraying exercise.
- For purpose of attaining the desired seeding density on the ground, the flight operator must conduct a calibration run. A calibration run allows the aircraft operator to set the hopper's release gate to be of defined slot in order to ensure a given quantity (kg) of seeds is dropped over an acceptable areal size (ha).

- Calibration is done though calculated settings to ensure the release-slot opens, to only allow certain quantity of seeds to yield the required seed and seedling density on the ground. Once set, seeds come out at pre-determined rate consistently as long as the slot remains open as set, and unblocked. To adjust the seeding density, the release-slot is adjusted accordingly.

  Calibration is achieved in two key steps as follows:

- Feeding the hopper with seeds of uniform diameter and of known weight in kilograms or few bags of known weight. The operator calibrates the hopper's seed release gate to a certain slot-size so as to attain a certain release-rate. The latter is mainly set based on the operator's length of experience. As the aircraft flies and undertakes aerial broadcasting, flight paths, swaths and coordinates are automatically tracked and once the seed load is exhausted, the area seeded by the defined seed load is computed using the data tracked on-flight. Both the area (ha) and the seed load (kg) is used to compute the seeding rate (kg/ ha) achieved during the calibration run.

- Visual assessment/observation on the ground under the swaths wherein the seeds potentially fell, also ascertains the seeding rate achieved which can be defined as satisfactory or not. During this visual assessment exercise, ground crew may be distributed randomly under the seeded swaths, and within dimensioned sample plots, to count the seeds occurring by virtual of aerial seeding.

- Based on the computed estimation of the seeding rate and complimented by the visual assessment, fast decisions can be made on whether the set calibration has achieved the desired density of seeding, and whether or not this should be adjusted (to allow denser or thinner seeding rate).

- The decision on adjustment of calibration rate must consider whether or not the amount of available seeds would be enough to seed the targeted area.

- At the same time, ground crew can visually assess the results in random points, not necessarily counting but through observation. The ground crew will also need to check the edges of the flight swath, also assessing if the desired seeding density is being achieved. The observers should be equipped with GPS receivers to capture coordinates of the observation points, and log in the details in a prescribed form.

3.5 Preparation of tree seeds, logistics for transportation, storage and security of seeds

- The client is to make arrangement for seeds to be transported to the degraded forestland or landscape targeted for aerial seeding. Logistical arrangement for transport and for subsequent storage and security of the tree-seeds in the field must be finalized before the operation.

- Equally important are the arrangements for manpower to load the tree-seeds into the aircraft hopper. Such arrangements must also be finalized way before the operation. Use of local labour would be convenient hence budget provision ought to be arranged in advance by the client's office in-charge.

It is important to verify on the ground, conditions of roads from the airstrip to the forestland or landscape targeted for seeding, and make prior arrangement for transporting coordinating crew to the aerial seeding site

3.6 Maintenance of records during aerial seeding operations

- During the aerial seeding operation, log of the loaded quantity (kg) of seeds (and/or sacks) must be maintained and for each loading, counter-signed by client and flight operator.
- A logging form with space for counter-signing is required as well as arrangement for the client's officer who will be charge of the loading and thus maintenance of logging form.
- During the flight operations, the flight log (including time) and SATLOCK data (generated automatically by the aircraft) must be maintained by the service provider, eventually to be shared with the client at the end of the operation. The flight-paths tracked automatically (see sample in Annex 5) is also to be shared with the client.

3.7 In-situ assessment of the realized seeding rate

It is important to assess in-situ, the realized seeding rate, which is conducted through visual assessment/observation on the ground and is meant to support the calibration run. The in-site assessment should be conducted scientifically and therefore should be guided by a sub-protocol (see sample in Annex 6).

- A set of blocks (over which to conduct in-situ assessment) must be sampled in advance. Over these blocks, the assessment experiment should be laid prior to aircraft flying over the respective block.

- In the respective blocks, the experiment include the assessment plots measuring about 2 m * 2 m, set to represent different surface cover types (see example in Plate 1 in Annex 7), as mapped in the final delineation map.

- Polythene sheets are then placed on these plots. Some other assessment plots should be set by pegging pre-determined dimensions on roads.

- Verification of seeds sown on the ground during aerial seeding, is accomplished by actual counting of the seeds dropped by the aircraft within the assessment plots (see example in Plate 2 in Annex 7). The counts are thereafter calculated to derive estimate of number of seeds per hectare.

3.8 Soil sampling for assessing the baseline soil nutritional value and quality

Soil sampling over the assessment plots is also conducted in order to determine the quality of soils representing the varied surface cover types where tree-seeds lodged.

- Assessment should be a rapid soil sampling exercise, conducted during the aerial seeding operation and at pre-determined sites.

- Some soil characteristics can be observed and defined *in-situ* (including drainage characteristics of top soil, colour, nature of parent material and level of weathering), however top soil should be collected for laboratory analysis of key soil nutrients.

- Laboratory analysis based on the soil samples should aim to assess soil fertility and suitability for tree growth.

ANNEXES

Annex 1: Terms of Reference for the multi-disciplinary team charged with planning and execution of aerial seeding

Introduction

Application of aerial seeding technology in Kenya's forestry sector is relatively new, and therefore there are no standards or protocol to guide its implementation. Undertaking the technology first on a pilot basis will provide a learning opportunity through which to develop such standards and protocol. Designing of the seeding exercise should be scientifically sound so that lessons learnt feed into development of standards and protocols, and potentially usher a paradigm shift in forest rehabilitation in Kenya.

A multi-disciplinary technical team, drawing membership from various disciplines and institution, is expected to drive the process aerial seeding 10,000 ha in four forests, and steer it to completion. These Terms of Reference (ToR) elaborates the key deliverables expected from the team, lifespan or duration of the team, organizational structure of the team as well as communication and reporting.

Deliverables

1. Refine and enrich the draft plan of action for review and approval, outlining actions, required inputs and expected outputs and timelines, clearly emphasising the logical flow and justification for each action.
2. Prepare a budget corresponding to the plan of action.
3. Execute the plan of action in a cost-effective manner with consideration for value for money.
4. Consult and/or co-opt other members from public and private sector institutions for purpose of soliciting information deemed critical for

aerial seeding exercise such as the optimum flying parameters that would yield satisfactory seeding rate, such flying height and speed and resultant application rates, and resultant displacement of seeds on the ground (including the effect of wind).

5. Provide relevant support and documentation to the Supply Chain Management to effect the procurement of service (aerial seeding) provider(s), so as to fast-track the respective procurement and contracting in a timely manner.
6. Seek from experts and players in the industry, clarity on the key considerations that are critical to ensure that aerial seeding exercise is technically and properly executed.
7. For each of the target forests, design the experimental seeding exercise following sound scientific procedures in terms of delineation of the target sites a priori, proper determination of appropriate species, among others.
8. Assess and decide on the need (or not) for pre-treatment of seeds that are to be broadcast.
9. Through appropriate channels, secure the required tree seeds and necessary logistics for the seeding exercise on time.
10. Define checklist of inputs and /or requirements for successive aerial seeding operation.
11. Develop an elaborate design for the experimental exercise that will render itself eligible for comparative assessment of aerial seeding versus hand-broadcasting of seeds versus natural regeneration. The design should be backed by detailed documentation and protocols, corresponding to each target forest.
12. Define the key aspects of aerial seeding operation that requires clear standards and protocols.

13. Develop various standards and protocols necessary for aerial seeding for approval.
14. Prescribe practically feasible (financially and socially) strategies for protecting the seeded sites as well as a cost-effective budget for implementing these strategies as well as monitoring their effectiveness and deliverables by persons charge with implementing the strategies.
15. Develop protocol for assessing the rate of germination of seeds across the four target forests and over the sites that are seeded using aerial operation, hand-broadcasting, and those control sites under natural regeneration.

Lifespan of the team

The Multi-disciplinary Technical Team is expected to be active the whole learning phase of the 10,000 ha Aerial Seeding Exercise that will likely last one (1) year. This phase include the early preparatory stage, the execution stage of actual aerial seeding, the post-seeding protection of seeded sites for one year, as well as during the first (1st) and second (2nd) assessments of the germination rates of seeds. In implementation, the team is expected to strictly adhere to the set timeline of the 10,000 ha Aerial Seeding Exercise which will be clearly defined in the respective Action Plan.

Organizational structure of the technical team

The Leader of the Multi-disciplinary Technical Team is appointed by KEFRI through an appointment letter. Other team members have also been appointment thus confirming their membership to the team. The Team Leader will coordinate activities of the team including convening meetings. Given the importance of the exercise, all team members are expected to be fully active and participate in scheduled activities without fail.

Reporting

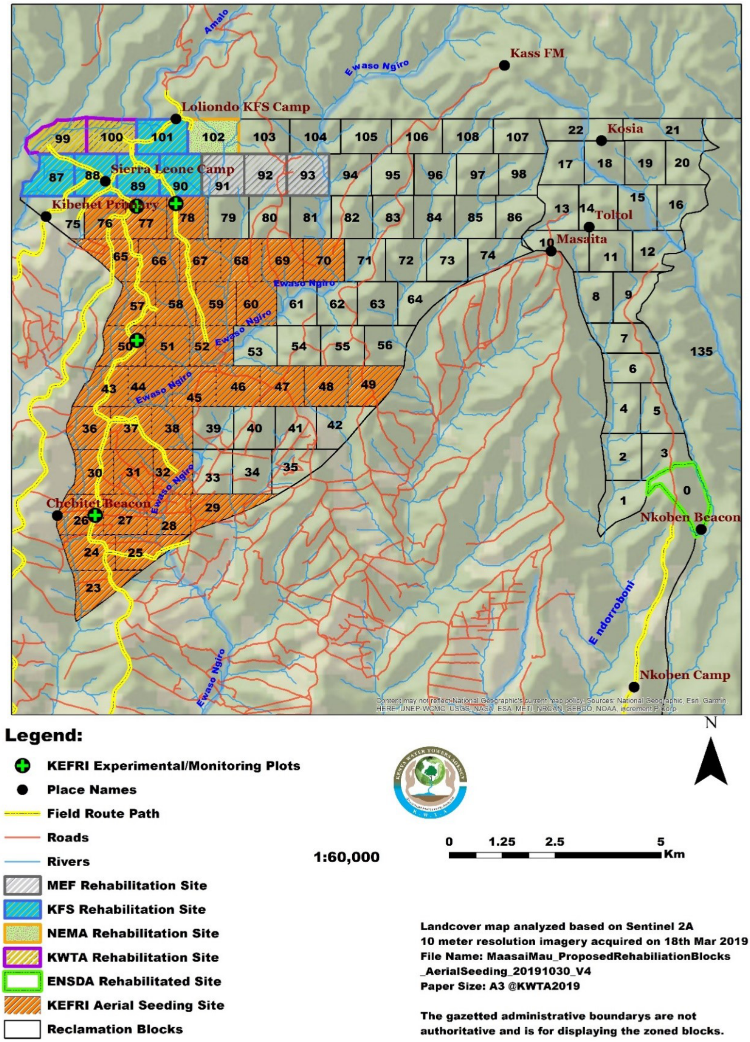
Proceedings of the Multi-disciplinary Technical Team shall be documented. Proceedings will include; minutes of each meeting, reports from workshops or retreats, documentation of key decisions and/or actions. These shall form critical documents for guideline of aerial seeding operation in Kenya and therefore must be documented. The team shall prepare monthly progress report.

Budget and financing

The team is expected to develop a budget alongside an Action Plan for review and approval. Disbursement of funds for team's activity will be in accordance with the Action Plan and the corresponding budget. The Action Plan will have clearly defined timeline and the execution of activities and thus budget expenditure will strictly be time-bound.

Annex 2: Final map delineating the areas earmarked for aerial seeding in Maasai Mau Forest

Aerial seeding was successfully conducted in November 2019, covering 3,600 ha. The final map indicates the various sites allocated to different entities.



Annex 3: Specifications for services of aerial seeding of degraded forests in Kenya

Eligible firm(s) appropriate to offer the said aerial seeding services in degraded forests in Kenya should fulfil the following requirements.

- Should have a well maintained aircraft fully equipped for aerial spraying or seeding of agricultural crops or tree seeds.
- Equipped with a hopper gate that is able to be calibrated to suit the application rate.
- With a satellite guide navigation system equivalent of SATLOCK.
- Must certify ALL the regulations for the Kenya Civil Aviation Authority (KCAA), including AOC and insurance.
- Experienced in relevant aerial applications in agricultural or tree seeding or equivalent.
- Ability to apply seed rate as determined by clients.
- Ability to adapt feedbacks about seeding rate and/or seeding density achieved, shared by ground crew.
- Willing to share with the client on time, the production of SATLOCK printouts following completion of a particular aerial tree seeding exercise.
- Ability to deliver the expected results on time.

Annex 4: Tender information for aerial tree seeding of Maasai Mau Forest

Introduction

The Government of Kenya plans to undertake aerial tree seeding of 10,000 ha of degraded areas in forested landscapes. The 10,000 ha area is distributed over four forest ecosystems namely; Mt. Kenya (3,500 ha), Aberdares (2,500 ha), Eburru (500 ha) and Maasai Mau (3,600 ha).

Given the unpredictable rainfall pattern in the country, the aerial seeding exercise has been scheduled for the 3,500 Ha Maasai Mau to take place on 1st November, 2019 as the area has been experiencing heavy rains over the last couple of weeks. The Government, through Kenya Forestry Research Institute (KEFRI) is therefore soliciting for quotations from firms that can urgently and within-a-short notice, be able to mobilize their aerial seeding facilities for aerial seeding of the target site in Maasai Mau Forests. The forest area targeted for this exercise is shown in digital map* (in Google Earth format, KML), which is also attached to this ToR.

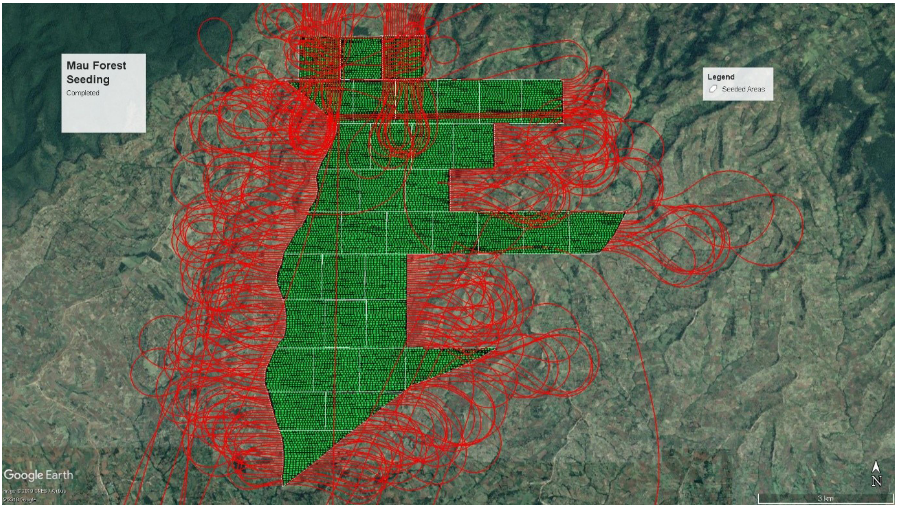
The tree seeds that are expected to be broadcast aerially are of different species and sizes. Twelve candidate species have been selected, analysed in terms of weight in stock, seeds per kilogram, and expected germination (Table 1). KEFRI will transport and secure the seeds to the airfield in Narok County (click Narok Airstrip, C12, Kenya-in Google Earth), which is about 45 km to the target seeding site. It is expected that the aerial seeding service provider will be responsible for loading the seeds into the hopper.

* For the aerial seeding work in Maasai Mau Forest, the digital map was shared via email. Additionally, the print-out final map was also attached to the TOR

Table A1: Characteristics of tree seeds

No	Species	Weight in Stock (kg)	Mean no. of seeds per kg	Mean number of expected seedlings/ kg
1	*Calodendrum capense*	20	825	490
2	*Cordia africana*	145	3,500	2,426
3	*Croton macrostachyus*	100	22,000	8,624
4	*Croton megalocarpus*	111	1,700	1,449
5	*Dombeya torrida*	20	217,500	147,683
6	*Hagenia abyssinica*	20	225,000	78,750
7	*Juniperus procera*	129	42,000	21,714
8	*Maesopsis eminii*	300	700	686
9	*Markhama lutea*	200	72,500	46,183
10	*Olea capensis*	25	3,000	945
11	*Podocarpus falcatus*	1	1,300	386
12	*Polyscias fulva*	50	400,000	162,000
13	*Vitex keniensis*	700	1,350	668
14	*Zathoxylum gilletii*	12	45,000	22,050
	Totals	**1832**		

Annex 5: Sample flight-paths tracked automatically during aerial seeding of Maasai Mau Forest where tree seeds were broadcast (green legend) and flight paths (red)



Annex 6: Sample sub-protocol to guide the visual assessment during calibration run and actual aerial seeding

Background

The aerial seeding method is a new tree establishment technology in Kenya where earlier experiences on tree aerial seeding has not been documented.

The pilot-test aims to provide information on estimated seeding rate per hectare from seed broadcasts done from an aircraft fitted with seed application equipment (hopper). The pilot will be the baseline for future reference.

The size of *Croton megalocarpus* seed will be the reference for calibration run. It is estimated to have about 1500 - 1700 tree seeds per kg. The thickness of the bark coat is 1.6 ± 0.6 mm and the approximate measurements of the seed is 2.2 - 2.4 cm long and 1.2 - 1.4 cm wide (Kipkosgei and Kamami, 2009). Ideally, all smaller-sized tree seeds to be used in the rehabilitation of the degraded sites ought to be benchmarked to the size of *C. megalocarpus* using the seed-balls bulked with either charcoal dust or sawdust.

Method

Nine plots measuring (15m x 12m) will be slashed to the ground and all debris removed to allow easy count of seeds that are broadcasted from the aircraft. However, instead of slashing the ground, a canvas or polythene sheet of a given dimension can be used). The plots will be laid such that they cover 3 types of terrain: 1=Flat, 2=Sloping and 3=Steep slopes and all replicated three times (Figure 1a). These plots will be laid out at intervals to be determined in the field based on the configuration of the field site and each plot geo-referenced using GPS. Within each plot size (15m x 12m), subplots of size 3m x 2m will be established and numbered 1-30 (Figure 1b). The layout of the plots will be as shown in Figure 1.

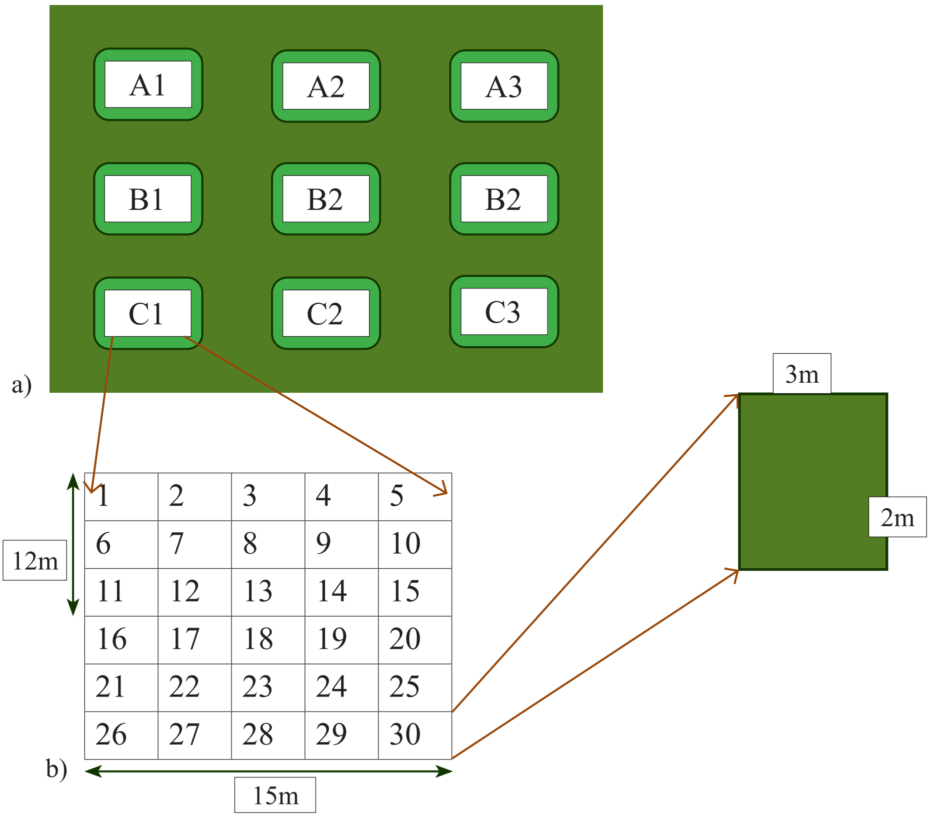


Figure 1: Layout of plots: a) Main plots and b) Subplots nos.1-30 of dimension 3m x 2m.

During the calibration run, the number of seeds that fall on at least 3 subplots in each of the nine main plots will be counted and relayed to Team Leader, who in turn will report success rate to the pilot of the aircraft until an optimum level is determined. The expected seeding rate is 7500 seeds/ha implying that on the ground; at least 0.75 seeds/m^2 are expected to be counted.

During the actual seeding, seeds will be counted in each of the 30 subplots within each main plot. Wooden pegs will be used to demarcate the main plot and sisal twine to partition the subplots. Counting and recording of the number of seeds on datasheet will be done sequentially as shown by the subplot numbers in Figure 1.

Note:
The amount of seed of tree species loaded into the aircraft will be recorded by a staff charged with maintaining seeds records at the airstrip. The time taken to complete the work will be given by the pilot of aircraft.

Annex 7: In-situ assessment of realized seeding rate

Plate 1: Laying the experiments

Plate 2: Verifying and counting the seeds on the ground

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