AMS-III.A

Small-scale Methodology

Offsetting of synthetic nitrogen fertilizers by inoculant application in legumes-grass rotations on acidic soils on existing cropland

Version 03.0

Sectoral scope(s): 15

United Nations
Framework Convention on
Climate Change

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1. Introduction

1.1. Background

1. The following table describes the key elements of the methodology.

Table 1. Methodology key elements

Typical projects	Application of inoculant on legumes in a legumes-grass rotation cropping on acidic soils on existing cropland substitutes and reduces the production and use of synthetic nitrogen fertilizer use
Type of GHG emissions mitigation action	GHG emission avoidance. Application of inoculant displaces more-GHG-intensive production of synthetic nitrogen fertilizers

2. Scope, applicability, and entry into force

2.1. Scope

2. This methodology covers project activities that involve the distribution and application of inoculant on legumes in a legumes-grass rotation cropping on acidic soils on existing cropland. In the absence of the project activity, legumes would have been fertilized with synthetic nitrogen fertilizers. Legumes and grass are fertilized with synthetic nitrogen fertilizer in the baseline. Grass is also fertilized with synthetic nitrogen fertilizer in the project situation, however with reduced application rates as compared to the baseline.

2.2. Applicability

3. The methodology is applicable:

(a) If the farmers participating in the project activity have grown legumes and grass in a legumes-grass rotation in the previous three complete rotations[1] without using any inoculant as a fertiliser for legumes, but have used synthetic nitrogen fertilizer for fertilizing legumes;

(b) Only the legume-rhizobia bacteria (inoculant) combinations specified in appendix 3 are eligible;

(c) For each farmer taking part in the project activity, reliable and verifiable data on the amount of synthetic nitrogen fertilizer used, separately for each crop type, in the previous three complete rotations of legumes and grass cropping, shall be available;

(d) No change in the types of crop cultivated takes place. In both the baseline and project situation legumes and grass are cultivated in rotations. No other changes in farming practices affecting fertilizer application, except the change in

[1] In a two-year cropping sequence this corresponds to the previous six years. In a one-year cropping sequence this corresponds to the previous three years.

application of inoculant and synthetic nitrogen fertilizer, are taking place during the crediting period;

(e) The project activity is accompanied by an educational programme which informs the farmers that adding any other source of N (e.g. synthetic fertilizer or organic fertilizer) on legumes is counterproductive and will make the rhizobia bacteria applied to the soil via inoculation ineffective;

(f) Fertilizers applied in the project scenario shall not add more non-nitrogen nutrients to the plantation than the baseline N fertilizer;[2]

(g) Farmers that take part in the project activity sign an agreement with the project participants that specifies that:

   (i) They did not use inoculants during the last three complete rotations;

   (ii) They will not claim emissions reductions for using inoculant on their land;

   (iii) The emission reductions generated by the project activity are owned by the project participants;

   (iv) They will apply inoculant following the recommendations made by national or supra-national agricultural research organizations;

(h) Also wholesalers and retailers of inoculant shall sign an agreement with the project participants that specifies that the emission reductions generated by the project activity are owned by the project participants and that they will instruct farmers to apply inoculant following the recommendations made by national or supra-national agricultural research organizations;

(i) The geographical/physical boundaries of the baseline electricity grid can be clearly identified and information pertaining to the grid and to estimate baseline emissions is publicly available;

(j) If the project participants are able to demonstrate that in the baseline scenario synthetic nitrogen fertilizer would be purchased from in-country production facilities or imported from a producing facility located in a Non-Annex I country.

4. Measures are limited to those that result in emission reductions of less than or equal to 60 kt CO_2 equivalent annually.

2.3. Entry into force

5. The date of entry into force is the date of the publication of the EB 81 meeting report on 28 November 2014.

[2] N, P, K (Nitrogen, Phosphorous, and Potash or Potassium) are the basic nutrients required for plant growth that are usually supplied by fertiliser applications. The measures under this methodology are related to supply of N nutrient through the application of inoculant. In order to ensure comparable total amount of nutrient supply in the project case as opposed to baseline, it is necessary to have similar amounts of total P and total K nutrient supplied in the baseline and project by fertilisers.

3. Normative references

6. Project participants shall apply the “General guidelines for SSC CDM methodologies”, and “General guidance on leakage in biomass project activities” (attachment C to Appendix B) provided at <https://cdm.unfccc.int/Reference/Guidclarif/index.html> mutatis mutandis.

7. This methodology also refers to the latest version of the following:

   (a) “AMS-I.D.: Grid connected renewable electricity generation”.

4. Definitions

8. The definitions contained in the Glossary of CDM terms shall apply.

9. For the purpose of this methodology the following definitions apply:

   (a) **Inoculation** - the practice of introducing rhizobia strains into the soil-plant ecosystem (via legumes seeds) in soils where no rhizobia is present, the number of rhizobia is insufficient to achieve the desired legumes yield and/or the rhizobia strains contained in the soil are ineffective;

   (b) **Rhizobia bacteria** - (Rhizobium, Bradyrhizobium, Mesorhizobium, Sinorhizobium and Azorhizobium): Bacteria that have the ability to form a symbiosis with legume species such as legumes. During the symbiosis, nodules (root cells invaded by rhizobia bacteria) are formed on the roots of the legumes. The rhizobia bacteria in the nodules convert gaseous nitrogen to ammonia via the nitrogenase enzyme (biological nitrogen fixation);

   (c) **Synthetic nitrogen fertilizer** - any synthetic fertilizer containing nitrogen (N). This may be a single nutrient products synthetic N-fertilizer (which only includes the plant nutrient N) or any other synthetic fertilizer containing N (e.g. multi nutrient fertilizers such N-P-K fertilizers);

   (d) **Legumes-grass rotation** - a cropping sequence on a particular field that includes legumes (species of leguminosae, as e.g. legumes, alfalfa, peas, lentilles etc.) and grass (e.g. corn) over a particular time interval (usually many years). The great majority of legumes-grass rotations have a two-year cropping sequence (one year legumes and the next year grass). In some parts of the world, a one-year cropping sequence may be found (summer legumes and winter grass); and sometimes, rotation patterns might involve one legume cropping followed by two other grass croppings or else;

   (e) **Crop** - cultivated plants or agricultural produce to be harvested as food, livestock fodder or for another economic purpose, considered as a group. Crops include legumes and grass;

   (f) **Existing cropland** - Land on which crops have been grown over the past ten years (at **least** for the majority of the period);

   (g) **Acidic soil** - Soil having a pH-level below 5.5.

10. The classification of land areas shall be based on the following classification system:

Table 2. Classification system of land areas

Factor	Unit	Classification	Remark	Reference
Soil organic carbon content	%	1. <1 2. 1 to 3 3. >3	1. Low 2. Medium 3. High	See Stehfest[3] (2005)
Soil pH	-	1. <5.5 2. 5.5 - 7.3 3. >7.3	1. Acidic 2. Neutral 3. Alkaline	See Stehfest[3] (2005)
Soil texture	Type	1. Coarse 2. Medium 3. Fine	1. Sandy, loamy sandy, sandy loam, silt loam, silt 2. Sandy clay loam, clay loam, silty clay loam 3. Sandy clay, silty clay, clay	See Stehfest[3] (2005)
Climate	Type	1. Boreal 2. Cold temperate dry 3. Cold temperate wet 4. Warm temperate 5. Moist 6. Tropical dry 7. Tropical moist 8. Tropical wet		See IPCC[4] (2006)
Soil moisture (soil drainage)	-	1. Well drained 2. Poorly drained		See Stehfest [3] (2005)

5. Baseline methodology

5.1. Project boundary

11. The project boundary encompasses the physical, geographical location of each area of cropland where the legumes-grass rotation takes place and inoculant is applied to legumes and synthetic nitrogen fertilizer is applied to grass. It also encompasses the production facility from where the inoculant used in the project activity is sourced.

5.2. Baseline emissions

12. Baseline emissions consist of CO_2 emissions from synthetic nitrogen fertilizer production. The baseline is based on the quantity of synthetic nitrogen fertilizer that each farmer would have applied in the absence of the project activity to grow legumes and grass. It shall be determined based on farmers' records of the previous three complete rotations for grass and legumes.

[3] Stehfest, E. (2005): Modelling of global crop production and resulting N_2O emissions. Dissertation. Universiy of Kassel.

[4] IPCC (2006): IPCC Good Practice Guidance and Uncertainty Management in National GHG Inventories.

13. The synthetic nitrogen fertilizer application rates to grass and legumes used for baseline calculations shall not exceed the fertilizer application rates recommended by national institutions; recommendations of international organisations (like FAO) for the specific country and soil type may be used if recommendations from national institutions/authorities are not available.

14. The CO_2 baseline emissions from the production of fertilizer applied on legumes *l* per farmer *i* per classified land area *j* are calculated as follows:

$$BE_{f,l,i,j} = \sum_{f}(ha_{l,i,j} \times AR_{l,i,j,f}) \times EF_{CO2,f} \qquad \text{Equation (1)}$$

Where:

$EF_{CO2,f}$	=	Emission factor for the production of synthetic nitrogen fertilizer (use local values or IPCC values or values from scientific literature[5]) (t CO_2/tonne synthetic nitrogen fertilizer)
$BE_{f,l,i,j}$	=	CO_2 baseline emissions from the production of the fertilizer *f* applied on the legumes *l* by the farmer *i* in the classified land area *j* (t CO_2)
$ha_{l,i,j}$	=	Area of land where inoculant is applied to legumes *l* by farmer *i* in classified land area *j* (ha)
$AR_{l,i,j,f}$	=	Average application rate of fertilize *f* to legumes *l* by farmer *i* in classified area *j* in the previous three complete rotations before joining the project (tonnes/ha)

15. The CO_2 baseline emissions from the production of fertilizer applied on grass with synthetic nitrogen fertilizer per farmer *i* per classified land area *j* are calculated as follows:

$$BE_{f,g,i,j} = \sum_{f}(ha_{g,i,j} \times AR_{g,i,j,f}) \times EF_{CO2,f} \qquad \text{Equation (2)}$$

Where:

$BE_{f,g,i,j}$	=	CO_2 baseline emissions from the production of the fertilizer *f* applied on the grass *g* by the farmer *i* in the classified land area *j* (t CO_2)

[5] In case of urea in the absence of reliable project specific data, a conservatively calculated value of 1.54 t CO_2e/tonne urea based on IPCC may be used which takes into account the fact that the total GHG emissions from urea would be GHG emissions during ammonia production – intermediate CO_2 storage in urea + CO_2 release due to urea application (see 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3: Industrial Processes and Product Use; Chapter 3.2 Ammonia Production) In case of other synthetic nitrogen fertilizers in the absence of reliable project specific data, conservative values may be calculated following guidance in appendix 2.

$ha_{g,i,j}$	=	Area of land where inoculant is applied to grass *g* by farmer *i* in classified land area *j* (ha)
$AR_{g,i,j,f}$	=	Average application rate of fertilizer *f* to grass g by farmer *i* in classified area *j* in the previous three complete rotations before joining the project (tonnes/ha)

16. The total CO_2 baseline emissions from synthetic nitrogen fertilizer production are determined as follows:

$$BE_y = \sum_{i,f} BE_{f,l,i,j} + \sum_{i,f} BE_{f,g,i,j} \quad \text{Equation (3)}$$

Where:

Σ_i	=	Sum of farmers *i* which take part in the project activity
Σ_j	=	Sum of classified land areas *j* where inoculant is applied in the project activity
BE_y	=	Total baseline emissions in year *y* (t CO_2e)

5.3. Project activity emissions

17. Project activity emissions consist of CO_2 emissions from the production of inoculant applied on legumes and CO_2 emissions from the production of synthetic nitrogen fertilizer applied on grass. Project emissions are determined as follows:

$$PE_y = \sum_{i} Q_{inoc} \times EF_{CO2,inoc} + \sum_{j} Q_f \times EF_{CO2,f} \quad \text{Equation (4)}$$

Where:

Q_{inoc}	=	Amount of inoculant applied to legumes by farmer *i* in the project activity (number of rhizobia bacteria)
$EF_{CO2,inoc}$	=	Emission factor for production of inoculant (t CO_2/unit of rhizobia bacteria)
Q_f	=	Amount of synthetic nitrogen fertilizer *f* applied to grass by farmer *i* in the project activity (tonne)
PE_y	=	Total project emissions in year *y* (t CO_2e)

18. The amount of synthetic nitrogen fertilizer and inoculant applied by the farmers shall be based on farmers' records for grass and legumes cropping and shall be cross-checked with records from inoculant suppliers, seed suppliers and synthetic nitrogen fertilizer suppliers.

19. The emission factor for production of inoculant ($EF_{CO2, inoc}$) shall be determined as:

(a) Aggregate annual CO_2 emissions from fossil fuel use and electricity consumption in the inoculant production facility from which the inoculant for the project activity is sourced, which is calculated as follows:

(i) All steps in the inoculant production process that require energy consumption shall be included, e.g. peat drying, peat grinding, peat and inoculant packaging, peat injection, fermentation, sterilization, liquid harvest and plant heating/cooling;

(ii) For the emissions from fossil fuel consumption the emission factor for the fossil fuel shall be used. Local values are to be used, if local values are difficult to obtain, IPCC default values may be used;

(iii) Emissions from electricity consumption are determined as per the procedures described in AMS-I.D;

(b) The aggregate annual CO_2 emission is divided by the annual amount of rhizobia bacteria produced by the inoculant production facility to calculate the emission factor for production of inoculant ($EF_{CO2, inoc}$).

5.4. Leakage

20. Leakage is to be considered (LE_y), if peat (a type of inoculant carrier) is dried at a facility, which is not included in the project boundary. In this case, the type and amount of energy required for peat drying shall be collected from the peat-drying facility. Each energy form is multiplied by an emission coefficient. For electricity, the emission coefficient is calculated in accordance with provisions under category I.D. For the emissions from fossil fuel consumption the emission factor for the fossil fuel shall be used. Local values are to be used, if local values are difficult to obtain, IPCC default values may be used. The calculated leakage emissions shall be deducted from the emission reductions.

6. Monitoring methodology

21. For each farmer *i* taking part in the project activity the historic synthetic nitrogen fertilizer application rate of fertilizer *f* for legumes and grass separately in the previous three complete rotations shall be established before joining the project activity. Also the yield per crop per hectare during the last three complete rotations shall be established. It shall be verified that no inoculant was used for fertilization of legumes in the previous three complete rotations.

22. Monitoring shall include all farmers *i* that take part in the project activity. The following parameters shall be monitored:

(a) Ha of crop planted;

(b) Classification of each land area *j* according to classification system of paragraph 10;

(c) The quantity of inoculant applied by the project activity (number of rhizobia bacteria);

(d) Amount of urea applied;

(e) Amount of other fertilizers applied (chemical fertilizers as well as organic fertilizers);

(f) Crop yield per crop per hectare.

23. Farmers' records (separately by crop type and land area *j*) shall be used along with other means for monitoring the above parameters.

24. It shall randomly be verified whether the farmers took part in an educational programme concerning application of inoculants (see applicability condition 3(d)) and whether inoculant has been applied following the recommendations made by national or supra-national agricultural research organizations (see applicability condition 3(e)).

25. Farmers' records shall be cross-checked with records from inoculant suppliers, seed suppliers, and synthetic nitrogen fertilizer suppliers. In case of discrepancies between the records of the farmers and those from inoculant supplies, seed suppliers or synthetic nitrogen fertilizer suppliers the most conservative value shall be taken.

26. In order to monitor whether the farmers have, contrary to the aim of the project, applied synthetic nitrogen fertilizer or organic fertilizers to the legumes, it shall be checked by an independent third party whether the fields where legumes has been planted by the farmers show signs of synthetic nitrogen fertilizer/other fertilizer application. If any field of a farmer does show such signs, all the land areas of this particular farmer included in the project boundary will be excluded from the emission reductions calculation for the given year. For reasons of conservativeness it shall be ensured that at least one field of each farmer is randomly selected for a field visit.

27. As synthetic nitrogen fertilizer might be applied in split applications:

(a) The field visits shall be conducted as follows:

(i) Once at planting; and

(ii) Again right before flowering;

(b) The independent third party will visit a sample of fields:

(i) For the first time four weeks after planting; and

(ii) A second time eight weeks after planting (in case the plants should by then not have flowered, the fields shall again be visited twelve weeks after planting or even sixteen weeks after planting);

(c) During the field visits the monitoring protocol contained in appendix 1 shall be followed;

(d) The independent third party conducting the field visits shall be a qualified field technician or an agronomist.

28. While visiting the fields the independent third party will also check the farmers' records on use of synthetic nitrogen fertilizer, inoculant, and organic fertilizers.

29. The origin of the synthetic nitrogen fertilizer, to ensure that the requirements under paragraph 3(h) are met, shall be checked.

30. The total quantity of inoculant produced and the fossil fuel and/or electricity consumption of the inoculant production facility (number of rhizobia bacteria) shall be monitored:

    (a) During the field visits the monitoring protocol contained in appendix 1 shall be followed;

    (b) The independent third party conducting the field visits shall be a qualified field technician or an agronomist.

31. The emission reduction achieved by the project activity will be determined as the difference between the baseline emissions and the project emissions and leakage.

$$ER_y = BE_y - PE_y - LE_y \qquad \text{Equation (5)}$$

Where:

ER_y	=	Emission reductions in year *y* (t CO_2e/y)
LE_y	=	Leakage emissions in year *y* (t CO_2e/y)

7. Project activity under a programme of activities

This methodology is also applicable to project activities under a programme of activities.

Appendix 1. Field visit monitoring protocol for synthetic nitrogen fertilizer and inoculant application

1. The following monitoring procedure shall be implemented to monitor the fields where legumes and grass is cultivated in rotations. It shall be administered by a qualified independent agronomist or field technician.

2. The agronomist will be informed when the legumes seed is being planted. Four weeks after planting, the agronomist will visit the farms and randomly select a field. Using an internationally accepted random soil sampling procedure, e.g. the procedure as described in "Soil Sampling",[1] the agronomist will pull up legumes plants to observe the nodules at each sample spot.

3. The agronomist will compare the size of the nodules to a photo chart of nodules. Nodules formed in the presence of synthetic nitrogen fertilizer or other exogenous sources of fertilizer will be small and will appear weak.

4. Next, the agronomist will slice open the nodules and look at the colour inside. The agronomist will compare the colour to a photo chart showing the inside colour of nodules. If the nodules are pink to bright red, the nodules are biologically fixing nitrogen. If the nodule slices don't have a colour or are light pink the plant has been fertilized with an exogenous source of nitrogen.

5. Summary: Plants exhibiting biological nitrogen fixation (BNF) are characterized by large, healthy nodules that, when cut open, are bright pink to red inside. Plants fertilized with synthetic nitrogen fertilizer or an exogenous source of nitrogen are characterized by small, weak nodules that, when cut open, have no colour or have a very light pink colour.

6. All observations will be recorded by the agronomist each time a field is visited and inspected.

[1] "Sampling", by Dr. H. Reetz, http://www.rainbowplantfood.com/agronomics/efu/sampling.pdf accessed on 14-04-2008.

Appendix 2. Guidance for conservative calculation of emission factor for synthetic N-fertilizers other than urea

1. A conservative emission factor for any synthetic nitrogen fertilizer can be calculated as long as the mass ratio of N in the fertilizer is known using the following formula:

$$EF_{CO2,f} = Ncont_f \times 1.7$$

Equation (1)

Where:

$EF_{CO2,f}$	The emission factor for the production of fertilizer *f* (t CO_2/tonnes fertilizer *f*)
$Ncont_f$	The *N* content of fertilizer *f* on a mass ratio basis (see table 1 below for examples for common synthetic N fertilizer types)
1.7	A conservative emission factor for ammonia production in t CO_2/tonnes N

Table 1. Selected synthetic nitrogen fertilizer types and their *N* content

Synthetic nitrogen fertilizer types	N content (% of mass)
Single nutrient products N-fertilizer	
Anhydrous Ammonia (NH_3) "Ammonia"	82
Ammonium Sulfate [(NH_4)2SO_4]	21
Monoammonium Phosphate (MAP)	11
Diammonium Phosphate (DAP)	18
Ammonium Nitrate (NH_4NO_3)	33.5
Calcium Ammonium Nitrate (CAN)	26
Any other synthetic nitrogen fertilizer (e.g. multi nutrient fertilizers (N-P-K))	**Depending on type of fertilizer**

Appendix 3. Eligible legume-rhizobia combinations

Table 1. Eligible legume-rhizobia combinations

Genus (rhizobia)	Species (rhizobia)	Hosts (legumes)
Rhizobium		
	R. meliloti	*Medicago* (Alfalfa) *Melilotus* *Trigonella* spp.
	R.fredii	*Glycine max,* (Soybean) *Glycine soja*
	R. leguminosarum bv. viciae	*Vicia fava* (Faba bean) *Pisium sativa* (pea) *Lathyrus* spp.
	R. leguminosarum bv. trifolii	*Trifolium* spp. (clovers)
	R. leguminosarum bv. phaseoli	*Phaseolus vulgaris* (common bean)
	R.tropici	*Phaseolus vulgaris,* (common bean) *Leucoena* spp (Ipil Ipil(in Philippines)) *Macroptilium* spp.
	R. etli	*Phaseolus vulgaris* (common bean)
	R.galegae	*Galega officinali* *G.orientalis*
	R.loti	*Lotus* spp. (Birdfoot trefoil)
	R.huakuii	*Astragalus sinicus* (Chinese milk vetch or Renge)
	R.ciceri	*Cicer arietinum*
	Rhizobium sp. strain NGR234	tropical legumes *Parasponia* etc.
Bradyrhizobium		
	B. japonicum	*Glycine max* *Glycine soja*
	B.elkani	Glycine max Glycine soya *Macroptilium* spp.
	Bradyrhizobium sp.	*Vigna* (cowpea) *Arachis* (peanut) Many tropical legumes
	Bradyrhizobium sp. strain *Parasponia*	*Parasponia* spp.
Azorhizobium		
	A.caulinodans	*Sesbania rostrata (*stem nodules)

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Document information

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03.0	28 November 2014	EB 81, Annex 27 Revision to streamline the sources and calculations of default emission factors.
02	17 July 2009	EB 48, Annex 17 Revision to include options to choose from a range of grass-legume combinations for the project; broader range of eligible baseline nitrogen fertilizer usage and guidance for determining the emission factor for those fertilisers.
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