Reef Credit method for accounting fine sediment abatement through improved grazing land management.

Version 1.0

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Method Title

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Version

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Consultation Process

The Method resulted from discussion at two workshops, March 2022, and February 2023.

Method Concept

This Methodology, referred to as the Method herein, describes the approach to achieve and quantify reductions in Fine Sediment (FS) from hillslope soil losses in rural landscapes through improved grazing land management. Sediment calculations under this Method are based on a hillslope soil loss model applied by the Australian and Queensland Governments known as the Revised Universal Soil Loss Equation (RUSLE).

Application of this Method will generate Reef Credits that incentivise landholders to achieve FS abatement. Grazing land management improvements under this Method aim to achieve a high level of ground cover before high intensity rainfall periods, reducing FS run-off and maximising the benefits to local waterways and the Great Barrier Reef.

This Method minimises the effects of external influences such as seasonality by using Dynamic Reference Cover Modelling (DRCM), thus increasing the degree of confidence that observed changes in ground

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cover are attributable to the project activities rather than naturally occurring fluctuations and/or climate driven trends.

It is anticipated that some projects developed under this Method may occur in conjunction with other ecosystem service market opportunities (e.g. soil carbon farming on grazing lands), subject to satisfying the eligibility criteria of each scheme.

Cite this Method

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1. Project Description

1.1 Governing Documents

- Reef Credit Standard
- Reef Credit Guide

1.2 References

This methodology references the following policy documents and tools:

- Reef 2050 Long Term Sustainability Plan
- Reef 2050 Water Quality Improvement Plan 2017-2022
- Paddock to Reef Program Grazing Water Quality Risk Framework
- Paddock to Reef Integrated Monitoring, Modelling and Reporting Program 2018-22
- Agriculture Environmentally Relevant Activity (ERA) standard – Beef cattle grazing in the Great Barrier Reef catchment
- Tool for the Demonstration and Assessment of Additionality in Reef Credit Projects
- Reef Credit Grazing Land Management Explanatory Statement
- Refer to Section 7 for all other references.

1.3 Summary Description of Methodology

This methodology (here onwards called the 'Method') describes the approach to achieve and quantify reductions in Fine Sediment (FS) from hillslope soil losses from rural landscapes through improved grazing land management within the Great Barrier Reef catchment area.

The core Method components include:

- **Determine eligibility:** Sets the criteria for eligibility of projects under the Method and the Reef Credit Standard, including but not limited to, additionality.
- **Establish project boundaries and scope:** Provides the rules for defining the geographical and temporal boundaries of the project, scope of activities, and pollutant pools to be accounted for in the project.
- **Quantify FS proportion:** Describes the requirements for project soil sampling.
- **Establish rainfall monitoring:** Provides the requirements for rainfall monitoring for erosivity measurements.
- **Quantify baseline project ground cover difference respecting regulatory minimums:** Details how to calculate the baseline spatial ground cover difference from surrounding dynamic reference pixels, respecting regulatory ground cover minimums.
- **Quantify baseline FS loss:** Details how to determine projected FS loss that would have occurred under the modelled baseline scenario by adjusting the satellite derived ground cover to match projected ground cover.
- **Quantify project FS loss**: Details how to determine project FS loss for the monitoring period using satellite derived ground cover.
- **Quantify FS reductions:** Details how to determine the reduction in FS resulting from project activities at end of catchment for the monitoring period.
- **Quantify Reef Credit units:** Outlines the steps to determine the number of Reef Credits based on calculated FS reductions.

- **Project Monitoring:** Provides the rules for the project monitoring and identifies parameters to assess compliance with the grazing land management strategy.

1.4 Project Activities

The scope of this Method includes the implementation of improved grazing land management to reduce the amount of FS loss. The Method allows for a range of practice changes that are reasonably expected to increase ground cover. The Method is not limited to the activities described in Section 2.3, but the project must provide a Grazing Land Management Plan (GLM Plan) as part of the Reef Credit Project Summary that describes the proposed activities for the project duration.

1.5 Definitions

- **Abatement:** The reduction in Fine Sediment delivered to the Great Barrier Reef resulting from interventions, calculated as the difference between the baseline and project sediment loss.
- **Additionality:** As defined in the Reef Credit Definitions, see also Section 2.5.
- **Baseline period:** January 2017 to Project Start Date.
- **Broadscale clearing:** Removal of woody vegetation implemented at a paddock scale and resulting in the conversion from >20% forest canopy cover to <20% forest canopy cover.
- **Business As Usual (BAU):** As defined by the Reef Credit Definitions.
- **Crediting period:** As defined by the Reef Credit Definitions. For this Method the period is equal to 25 years.
- **Disturbance event:** Either a natural disturbance event as defined by the Reef Credit Definitions that would result in an immediate loss of ground cover (such as unplanned fire activities) or any pre-planned event that would result in an immediate loss of ground cover such as planned fire activities or broadscale clearing.
- **Dynamic Reference Cover Modelling (DRCM):** Is the process of continuously updating a set of reference points to accurately represent the evolving dynamics of a changing environment (Bastin et al., 2012).
- **DRCM buffer area:** A zone around project area that accommodates variations in data or environmental changes, ensuring robust coverage and representation.
- **Fertiliser application:** Refers to the process of applying synthetic nutrients to soil or plants to enhance their growth and productivity.
- **Fine Sediment (FS):** Particles < 20 µm, i.e., the clay and fine silt particle size fraction of the soil material judged to be the component most likely to impact the Great Barrier Reef.
- **Grazing Land Management (GLM) Plan**: Documented proposal for implementing project activities for the duration of the project period. Requirements outlined in Section 4.
- **Great Barrier Reef catchment area**: As defined by the Reef Credit Definitions.
- **Ground cover:** Refers to the vegetation or materials that grow and spread across the ground surface, providing erosion control, and habitat for various organisms.
- **Irrigation:** Is the artificial application of water to land or soil to assist in the growth of crops or vegetation.
- **Leakage:** As defined by the Reef Credit Standard, see also Section 2.6
- **Monitoring period:** As defined in the Reef Credit Standard. For this Method, the minimum monitoring period length is 6 months, and the maximum monitoring period length is 5 years.

- **NRM Regions:** The six Natural Resource Management Regions as defined by the Queensland Government that comprise the catchments that drain to the Great Barrier Reef. In Cape York this is the eastern draining catchments only.
- **Project application:** As defined by the Reef Credit Definitions.
- **Project area:** As defined by the Reef Credit Definitions.
- **Project end date:** As defined by the Reef Credit Definitions.
- **Project start date:** As defined by the Reef Credit Definitions.
- **Reef Credit:** As defined by the Reef Credit Definitions.
- **Reef Credit Accounting Zone (RCAZ):** Spatially explicit area delineated according to Section 3 of the Method in which project activities and project accounting occurs.
- **Reference areas:** Minimally disturbed areas used to benchmark changes in ground cover through time. These areas act as a synthetic control area that is compared against project areas.
- **Revised Universal Soil Loss Equation (RUSLE):** A predictive model used to determine hillslope soil erosion rates by factoring in the effects of rainfall, soil type, slope, land cover, and conservation practices. The RUSLE does not estimate sediment deposition or gully erosion, (14 et al., 1997; Wischmeier & Smith, 1978).
- **Regulated Minimum Ground Cover (RMGC)**: The greater of either the regulatory minimum ground cover value at time of project registration, or the regulatory minimum ground cover at time of project reporting.
- **Sediment Delivery Ratio (SDR):** The ratio of sediment yield at the catchment outlet to the amount of soil loss from hillslopes.
- **Storm:** Periods of rainfall separated by periods of no rainfall for more than 6 hours that exceeds either 12.7mm total, or with a maximum 12-minute rainfall of greater than 5.6mm, (Renard et al., 1997; Wischmeier & Smith, 1978; Yu, 1998).
- **Woody vegetation:** Perennial plant that has primary supporting structures consisting of secondary xylem.
- **Wooded Foliage Projection Cover:** The measurement or estimation of the area covered by tree canopy or foliage in a wooded or forested area.

1.6 Documentation Requirements

1.6.1 Project Application

When applying for a Reef Credit project, the project documentation must include a Project Summary. The Summary must include:

a. Names of project proponents and names of any individual or entity with interest in the land parcel or enterprise.
b. Description of project including:
    i. Spatial files defining the Project Area.
    ii. Spatial files defining DRCM Buffer Area.
    iii. Spatial files defining RCAZ.
    iv. Estimate of average baseline FS loss.
    v. Estimate of abatement potential over the crediting period.

The project application must also include the first version of the Grazing Land Management (GLM) Plan and a Project Eligibility Report outlining how the project complies with:

a) The Reef Credit Standard, including but not limited to legal right and consent; and
b) The eligibility requirements specified in the Section 2 of the Method, including but not limited to the demonstration of additionality; and
c) Any legislative requirements.

1.6.2 Project Crediting

When applying for issuance of Reef Credits, project documentation must include:

- Project Summary
- Project Eligibility Report
- Grazing Land Management Plan
- Spatial Report
- Project Abatement Report
- Project Monitoring Report
- Evidentiary Documents including spatial files as required by Section 6.

In addition to the requirements outlined in this Method, the project documentation must address how the project complies with the Reef Credit Standard when applying this Method (e.g. documentary evidence of land ownership or rights to land management over the project area) and meets any legislative requirements.

Crediting applications must also be accompanied by a third-party verification report if required and prepared in accordance with the Reef Credit Standard.

2. Eligibility

This section outlines the project eligibility criteria to implement this Method under the Reef Credit Standard. For each of the eligibility criteria, credible evidence in the form of analysis, documentation, and/or third-party expert reports are required as part of the project application.

2.1 Location

The proposed project area must be located within the boundaries of one of the following Great Barrier Reef NRM Regions:

- Cape York Peninsula (eastern seaboard draining catchments only)
- Wet Tropics
- Burdekin
- Mackay-Whitsunday
- Fitzroy
- Burnett-Mary

2.2 Project Land Characteristics

The Project Area must only include land where:

- Grazing is the principal land use for 7 years prior to Project Start; and
- Broad scale clearing of woody vegetation has not occurred within the previous 7 years*; and
- Project activities are reasonably expected to improve ground cover beyond what is required by existing legislation and/or other pre-existing formalised obligations; and
- The project proponent has the legal right to manage implementation of project activities.

* Land that has been broadly cleared of woody vegetation can be included in the RCAZ for a crediting period if the following conditions are met:

- At least 14 years must have passed since the last clearing of the land; and
- The 7 years immediately following the clearing must not be part of the baseline scenario used for assessing that land.

This means that the land can be credited towards conservation goals after a 14-year period, provided the first 7 years after clearing are excluded from the baseline assessment.

2.3 Project Activities

Project activities as described in section 1.4 must:

- Include one or more grazing practice change activities that is reasonably expected to increase ground cover; and
- Be consistent with the relevant regional plans and strategies such as a regional NRM Plan, or otherwise provide justification as to why the regional plan should be over-ridden; and
- Be compliant with all Australian, State, and Local Government laws and regulations; and
- Demonstrate additionality.

Practice changes reasonably expected to increase ground cover may include:

- Matching stocking to forage budgets.
- Rotational grazing and wet season spelling, 'periods of rest'.
- Infrastructure investment, i.e., fencing and water.

- Land remediation, i.e., pasture and native vegetation management, weed control, feral animal control.
- Other interventions undertaken to increase ground cover which are fully described by the proponent in the GLM Plan.

2.3.1 Exclusions

The following activities are not eligible for Reef Credits under this Method:

- Irrigation, including pasture irrigation; or
- Fertiliser application as a new activity i.e. increased application of fertiliser compared to BAU; or
- Broadscale clearing of woody vegetation; or
- Any activity on the negative list outlined in the Reef Credit Standard.

2.4 Land Use Change

If the project involves a change in land use to carry out an eligible project activity, the project proponent must have obtained all necessary permits and approvals (all levels of government as necessary). Proponents must also outline in the GLM Plan the steps taken to ensure the project will not have a negative impact on catchment water quality.

2.5 Additionality

For a project to qualify as additional it must initially fulfil the following requirements:

- Reef Credits can only be generated from activities that are additional to that required by laws, regulations, and/or other formalised obligations; and
- The project activities must be on the positive list outlined in the Reef Credit Standard or Method; and
- The project activities must not be on the negative list outlined in the Reef Credit Standard or Method.

Project proponents must demonstrate additionality by applying the Reef Credit Additionality Tool.

For example: If current Reef Regulations specify minimum standards such as 50% ground cover for grazing enterprises within the Great Barrier Reef catchments areas, projects can only generate Reef Credits on improvements to ground cover above and beyond 50%. Refer to Section 5 Equation 5, which requires incorporation of regulated minimums into the calculations.

2.6 Leakage

Leakage may be considered to occur if there is a displacement of activities that increase FS erosion relative to BAU on areas within the Great Barrier reef catchment and outside of the project RCAZ due to the implementation of the project.

For example: By reducing grazing pressure within the project RCAZ there might be a consequential increase in grazing pressure, that results in beyond BAU erosion, on areas outside the RCAZ.

This includes:

- **Scenario 1:** Land beyond the Project Area (including other properties) within operational control of the project participant/s of the same agricultural enterprise, i.e., grazing.

- **Scenario 2:** Land within the Project Area but not within the RCAZ, i.e., land not monitored by satellite ground cover mapping due to having > 60% woody vegetation.

Project proponents must complete the steps under 2.6.1 at the time of the project application and each monitoring period to determine if there is a risk of project leakage and if so, implement the appropriate procedure to account for leakage.

2.6.1 Determine if the project may be at risk of leakage

The risk is an increase in FS erosion in areas outside the RCAZ, to maximize the Reef Credit benefit within the RCAZ. The following applies to manage this risk under each leakage scenario:

Scenario 1 - Land beyond the Project Are**:**

- **Step 1:** Identify if the landowner or land manager is responsible for managing other agricultural land within the Great Barrier Reef catchment area, outside the Project Area. If the answer is 'no,' the risk of project leakage is considered zero, and the project proponent can proceed to Section 3. If the answer is 'yes,' this land is considered to be at risk of leakage. The project proponent must follow the procedures for mapping land at risk of leakage as described in Section 3 - Project Mapping, and then move on to Step 2.
- **Step 2:** Once the area of land at risk has been identified, assess the credible risk that the project might increase Business As Usual (BAU) FS erosion on this land. Include a description of BAU activities that could lead to FS erosion and evaluate how the project might shift these activities in a way that could materially increase erosion. This assessment should be documented in the GLM Plan. If the assessment finds no plausible risk of increased erosion due to the project (e.g., due to existing land management practices), then the risk of project leakage is considered unlikely, and the proponent should proceed to Section 3. If the assessment finds a plausible risk of increased erosion due to the project, then the risk of project leakage is considered likely, and you should proceed to Step 3.
- **Step 3:** If the risk of project leakage is considered likely, the proponent must include a leakage risk mitigation strategy in the GLM Plan. This strategy should detail the steps that will be taken to prevent leakage. Compliance with this strategy must be monitored and reported at the end of each monitoring period. If compliance is demonstrated, the residual risk of leakage is considered unlikely. If compliance cannot be demonstrated, the residual risk is likely, proceed to Step 4.
- **Step 4:** The project proponent must determine the best method to conservatively quantify FS loss due to leakage. This involves calculating the change from BAU activities and making a leakage deduction from the final Reef Credit volume, as outlined in Section 5, Equation 15.

Scenario 2 - Land within the Project Area but not within the RCAZ**:**

- **Step 1:** Check if the Project Area and the RCAZ (Reef Catchment Area Zone) are the same for the monitoring period. If they are the same, the risk of project leakage is considered zero for this scenario. If they are not the same, proceed to Step 2.

- **Step 2:** For land within the Project Area but outside the RCAZ, if FS (fine sediment) loss can be calculated as described in Section 5, any increase in FS loss within this area compared to the expected baseline must be subtracted from the total abatement for the monitoring period, according to Section 5 Equation 15. If FS loss cannot be calculated for this land as described in Section 5 Equation 15, proceed to Step 3.
- **Step 3:** For land within the Project Area but outside the RCAZ, where FS loss cannot be calculated (e.g., wooded areas not covered by ground cover imagery, such as areas having > 60% woody vegetation), the proponent must include a leakage risk mitigation strategy in the GLM Plan. This strategy should outline the steps to prevent leakage. Compliance with this strategy must be monitored and reported at the end of each monitoring period. If compliance is demonstrated, the residual risk of leakage is considered unlikely, and the proponent should proceed to Section 3. If compliance cannot be demonstrated, the residual risk of leakage is considered likely, and you should proceed to Step 4.
- **Step 4:** The project proponent must determine the most conservative method to quantify FS loss due to leakage. This involves calculating the change from Business As Usual (BAU) activities and making a leakage deduction from the final Reef Credit volume, as specified in Section 5, Equation 15.

3. Project Mapping and Data Requirements

The boundaries of the Project Area, RCAZ, and all other mapping required for reporting must be delineated in accordance with the requirements of this section.

3.1 Geospatial capture

A project proponent may use any of the following sources of data to delineate the boundaries of, and features within the Project Area and RCAZ:

- Derived photogrammetry
- Air-photo photogrammetry
- Ortho-rectified aerial photographs
- Ortho-rectified satellite imagery
- Cadastral database

3.2 Fitness for purpose

Prior to using a dataset, project proponents should assess the appropriateness of the dataset for the intended use, or its fitness for purpose against criteria that include:

- Age
- Scale
- Resolution
- Accuracy
- Classification, aggregation, generalisation systems (for example, smoothing)
- Integrity of dataset

3.3 Accuracy

The minimum requirement for spatial data is a horizontal accuracy of at least 10 metres at 95 percent threshold. Evidence of this data accuracy must be included in the Spatial Report. For the RUSLE calculations, the accuracy of specified Queensland Government data, as supplied, is considered acceptable. Detail provided in section 3.4.

3.4 Data Requirements

Table 1 details data type, quality, and source for each RUSLE factor and source data.

Table 1: Data Requirements

RUSLE - Factor requirement	Data Type	Data Quality	Data Source (Below)
R - Rainfall	Raster	Derived from rainfall gauge data	(a)
K – Soil erodibility	Raster	From unaltered supplied source data.	(b)
L – Slope length	Raster / Constant	Constant = 1	(c)
Rock Factor – Surface armouring	Raster	From unaltered supplied source data.	(b)
S – Slope	Raster	From unaltered supplied source data.	(b)
P – Conservation (Practice factor)	Raster / Constant	Constant = 1	(c)

C – Cover management	Raster	From unaltered supplied source data.	(d)
Source Data	**Data Type**	**Data Quality**	**Data Source (Below)**
Ground cover	Raster	From unaltered supplied source data.	(e)
Sediment Delivery Ratio (SDR)	Raster	From unaltered supplied source data.	(b)
Fine Sediment Proportion (FS)	Raster	Derived from soil sampling	(f)
Regulated minimum ground cover (RMGC)	Constant	Constant – Reef Regulations	(b)

a) Derived using equation 11 with data from rainfall gauge, see Section 3.4.1.

b) Queensland government supplied

c) All areas given default factor of 1

d) Derived using equations 12 and 13 using ground cover

e) Derived from equation 1 with ground cover data sourced from Queensland government, with a minimum of blended monthly captures, 30m/pixel, and restricted to <60% woody vegetation. (At time of publication: TERN: Monthly Blended Ground Cover version 3 - Landsat and Sentinel-2, JRSRP algorithm, Queensland coverage).

f) Derived from results of the soil sampling, see Section 3.4.2.

Data layers without temporal variability are fixed as the most recent layers at the time of projected registration. Proponents can elect to incorporate all subsequent updated government layers at each report but must continue with all updated layers for subsequent reports.

3.4.1 Rainfall intensity measurement

Rainfall measurement is to be conducted within the project area using a calibrated tipping bucket rain gauge that can report in 6-minute increments (minimum) and capture the expected range of rainfall rates.

Flow rate accuracy is to be at least +/-5% under 200mm/hr with yearly verification of operation within the specified accuracy limit to be documented.

3.4.2 Project FS proportion

Prior to commencement of project, proponents are required to develop a Soil Sampling Plan as part of the GLM Plan for spatialising the FS proportion (refer definitions) within the RCAZ.

The Soil Sampling Plan stratifies the RCAZ for FS proportion sampling. The minimum number of strata is to be the number of unique values of the Soil Erodibility layer (K raster) that intersect with the RCAZ. Surface (0-15cm) soil collection points within identified strata will, at minimum, be the greater of three samples per strata or 1 sample per 200ha of strata. Particle size analysis that identifies the FS proportion (<20 μm) of bulked by strata samples is to be undertaken by a National Association of Testing Authorities (NATA) accredited laboratory.

Any existing data collected during the baseline period may be utilised in line with conditions stated above.

4. Grazing Land Management Plan

A Grazing Land Management (GLM) Plan for the Project Area must be prepared outlining the grazing management strategies that are expected to increase ground cover. The GLM Plan must contain:

- Description of the grazing enterprise, including all properties in Great Barrier Reef catchments area under management, or subject to management arrangements (e.g. agistment or other stock relocation activities).
- Description of the baseline period GLM activities undertaken on the Project Area.
- Any descriptions, assessments, strategies required to comply with Section 2.6 Leakage.
- Soil Sampling Plan, Section 3.4.2.
- Maps and spatial files that delineate:
    - Project Area
    - Reef Credit Accounting Zones
    - Land subject to risk of leakage
    - Paddock location and size
    - Ground cover trends across the Project Area
    - Exclusion areas
    - Soil stratification that complies with Section 3.4.2
    - Proposed and actual soil sampling locations
    - Proposed and actual rainfall monitoring location/s
    - Anticipated and actual disturbance event boundary/ies
- Description of proposed GLM activities for each monitoring period, such as:
    - Approach to measure and monitor pasture biomass and undertake forage budgets
    - Approach to manage and monitor stock numbers
    - Approach to manage leakage risk
    - Approach to manage and monitor planned and unplanned disturbance events

The GLM Plan must be kept for the duration of the crediting period and be reviewed, updated, and submitted at the end of each monitoring period with the application for Reef Credits.

5. Project Accounting

Reef Credits are generated by calculating the difference in FS run-off between:

1. RUSLE from remotely monitored data; and
2. Modelled RUSLE from remotely monitored data adjusted using cover data from the baseline period.

Broadly, the project accounting steps require the following:

1. Identify baseline dynamic reference cover pixels
2. Determine monthly project baseline difference (including accounting for regulated minimums)
3. Identify project dynamic reference cover pixels
4. Determine monitoring period and adjusted ground cover
5. Determine RUSLE factors 'R', 'C' and modelled '$\dot{C}$'
6. Undertake sediment abatement calculations
7. Apply to relevant pools
8. Account for leakage
9. Account for disturbance events
10. Calculate Reef Credit

5.1 Identify Dynamic Reference Cover Pixels

Dynamic Reference Cover Modelling (DRCM) is used to adjust ground cover changes for seasonal influences. In this Method, minimally disturbed areas termed 'reference areas' are used to benchmark changes in ground cover through time. These areas can be thought of as a synthetic 'control' that are compared against areas where project activities have been implemented. This Method assumes that within reference areas, changes in ground cover result primarily from the influence of weather and climate conditions rather than grazing land management or other disturbances. Calculating the difference in ground cover between the reference and RCAZ is therefore a measure of grazing impact on ground cover.

DRCM is specifically used in this Method to determine the average monthly difference in ground cover between the reference area and RCAZ pixels. This calculation is undertaken for the baseline period (2017 to project registration) and in each Monitoring period (2017 to Monitoring Period end date). The average calculated in the Baseline is used to adjust the measured monthly cover in the Monitoring Period so the influence of weather and climate on ground cover can be removed and change attributed to project activities determined.

To identify the reference area cover pixels for the baseline period:

- Download ground cover data from 2017 to project registration date that includes the extent of the Project Area and the 10km DRCM buffer area.
- Identify the pixel-wise lowest ground cover percentage using all data. Create a minimum baseline period layer from this data (that is, the lowest average monthly ground cover within the baseline period for each pixel).
- Select all pixels within the highest 90-95 percentile range (Bastin et al., 2012) within the minimum baseline period layer.
- These are the baseline period reference area pixels that when averaged are used to determine the baseline period ground cover for each month, all other measured pixels within the RCAZ area are referred to as project area pixels.

To identify the reference area cover pixels for each month of the monitoring period:

- Download ground cover data from 2017 to the monitoring period end date that includes the extent of the Project Area and the 10km DRCM buffer area.
- Identify the pixel-wise lowest ground cover percentage for all data. Create a minimum layer from this data (that is the lowest average monthly ground cover from 2017 for each pixel).
- Select all pixels within the highest 90-95 percentile range (Bastin et al., 2012) within the minimum layer.
- These are the monitoring period reference area pixels that when averaged are used to determine the ground cover reference for each month, all other measured pixels within the RCAZ area are referred to as project area pixels.

The following equations are used to identify the dynamic reference pixels.

Note: Equations denote raw monthly data that spans across multiple years as i (January 2017, January 2018, …) and calendar month data (January) that has been averaged as j.

Equation 1 – Monthly ground cover proportion (GC_i)

For the month *i* the ground cover proportion (0 – 1) is derived from government supplied monthly blended ground cover as defined in Section 3.4:

$$GC_i = 1 - \frac{(BG\%_i)}{100}$$

Where:

GC_i = Ground cover proportion for raw data month *i.*

$BG\%_i$ = Bare ground percent for raw data month *i* from the Queensland Government.

Equation 2 – Minimum ground cover (GC_{min})

Project area spatial minimum ground cover raster for all months (baseline or baseline and monitoring period):

$$GC_{min} = minimum(GC_k, GC_l, GC_m \ldots.)$$

Where:

GC_{min} = Spatial minimum ground cover of all raw monthly data (either baseline or monitoring period).

GC_x = Ground cover for all raw data months (*k, l, m…)* within baseline (2017 to project start) or within baseline and monitoring period (2017 to monitoring period end) – 10km DRCM buffer area extent.

Equation 3 – Reference cover pixel selection (GC^{ref})

Selection of dynamic reference cover pixels as a subset of the minimum cover raster layer:

$$GC^{ref} \subset GC_{min} \,(where\ 90^{th} percentile \le GC_{min} \le 95^{th}\ percentile)$$

Where:

GC^{ref} = Reference pixels as a subset of the captured minimum ground cover raster (spatial wise pixels to be reference pixels under seasonal variation with least influence from management activities).

GC_{min} = Spatial minimum ground cover of all raw monthly data (either baseline or monitoring period).

Equation 4 – Project area pixel selection ($GC^{project}$)

RCAZ with reference pixels removed:

$$GC^{project} \subset RCAZ \;\; (\, GC^{ref} \; removed)$$

Where:

$GC^{project}$ = Area within the project that has been defined as project measurement areas.

$RCAZ$ = Reef Credit Accounting Zone.

GC^{ref} = Spatial area within the 10km buffer area that has been defined as dynamic reference pixels.

5.2 Determine Monthly Project Baseline Ground Cover Difference

(Baseline scenario)

The baseline is the difference in average ground cover between the reference and project pixels, starting from 2017 to project registration. A baseline ground cover is required for each calendar month *j.*

The following equation is used to identify the calendar monthly baseline ground cover.

Equation 5 – Monthly difference between average reference ground cover and individual project area pixels accounting for regulated minimum ground cover (GC_i^{diff})

Raw data monthly difference in ground cover between the average of the reference area and project area individual pixel ground cover:

$$GC_i^{diff} = \begin{cases} mean(GC^{ref}[GC_i]) \; - \; GC^{project}[GC_i], & GC^{project}[GC_i] \geq RMGC \\ mean(GC^{ref}[GC_i]) \; - \; RMGC, & GC^{project}[GC_i] < RMGC \end{cases}$$

Where:

GC_i^{diff} = Difference in cover between the mean reference cover pixels and the individual project pixels for the raw data month *i.*

$mean(GC^{ref}[GC_i])$ = The average ground cover of all reference pixels for the raw data month *i.*

$GC^{project}[GC_i]$ = The individual pixel ground cover value for the project pixels during the raw data month *i.*

$RMGC$ = The regulated minimum ground cover proportion.

Equation 6 – Baseline average calendar monthly difference between reference ground cover and project area pixels (GC_j^{diff})

Baseline average calendar monthly difference in ground cover between the reference area and project area individual pixel ground cover:

$$GC_j^{diff} = mean(GC_i^{diff})$$

Where:

GC_j^{diff} = Average difference in ground cover between the mean reference ground cover pixels and the individual project pixels for the calendar month *j.* (Example: January average baseline ground cover difference).

GC_i^{diff} = Difference in ground cover between the mean reference ground cover pixels and the individual project pixels for the raw data month *i* over the calendar month *j.* (Example: January 2017, January 2018, January 2019….).

5.3 Determine monitoring period adjusted ground cover

(Project reporting period calculations)

Identify reference and project pixels in accordance with the approach described by Sections 5.1 and 5.2 for the baseline from 2017 to the monitoring period end date. Note that the reference ground cover pixels might be different from the baseline due to altered grazing practices, or external impacts in the DRCM buffer area. Calculate the difference in average ground cover between the monitoring period reference pixel average and individual project pixels. This is required for each month.

For reporting, download required ground cover layers and identify reference and project pixels using the same approach as baselining (from 2017 to project reporting date). Noting the reference ground cover pixels might be different from the baseline due to altered grazing practices or external impacts in the DRCM buffer area. Calculate the difference in average ground cover between the project reporting reference pixel average and individual project pixels. This is required for each month.

For each of the project area pixels, adjust the monthly monitoring period ground cover layer for the project area pixels to match the projected monthly difference from the baseline. This is the BAU scenario that will be used to calculate change in FS run-off. This adjustment accounts for extended periods of wet or dry weather.

The following equations are used to calculate the difference in ground cover.

Equation 7 – Difference in ground cover between project and reference ground cover pixels ($\widehat{GC}_i^{diff}$)

Calculating the difference for the monitoring period:

$$\widehat{GC}_i^{diff} = mean(GC^{ref}[GC_i]) - GC^{project}[GC_i]$$

Where:

$\widehat{GC}_i^{diff}$ = Difference between measured ground cover for month *i* in project monitoring period for reference ground cover pixels and project area pixels.

$mean(GC^{ref}[GC_i])$ = The average ground cover of all reference pixels for the raw data month *i.*

$GC^{project}[GC_i]$ = The individual pixel ground cover value for the project pixels during the raw data month *i.*

Equation 8 – Difference from the difference projected by the baseline, of the difference between the project area and the reference area ground cover (difference of differences) ($\widehat{\Delta GC}_i^{diff}$)

Calculating the difference of the ground cover difference from the baseline projected for the monitoring period:

$$\widehat{\Delta GC}_i^{diff} = \widehat{GC}_i^{diff} - GC_j^{diff}$$

Where:

$\widehat{\Delta GC}_i^{diff}$ = Monitoring period project area ground cover difference from reference pixels difference from projected baseline levels for raw data month *i* – Correction factor for measured actual project ground cover to projected ground cover from baseline monitoring period – Difference from the projected difference for each pixel in the project area.

GC_j^{diff} = Pixel wise baseline projected ground cover difference of average reference pixels and project area pixels during calendar month *j.*

$\widehat{GC}_i^{diff}$ = Pixel wise actual measured ground cover difference of average of the reference pixels and project area pixels during monitoring period raw data month *i.*

Equation 9 – Adjusted monthly ground cover – Projected from baseline ground cover difference (GCA_i)

Measured monthly ground cover adjusted to respect the difference projected from the baseline ground cover calculations:

$$GCA_i = GC_i + \widehat{\Delta GC}_i^{diff}$$

Where:

GCA_i = Adjusted ground cover proportion in raw data month *i*.

GC_i = Ground cover proportion in raw data month *i*.

$\widehat{\Delta GC}_i^{diff}$ = Monitoring period project area ground cover difference from reference pixels delta from projected baseline levels – Correction factor for measured actual project ground cover to projected ground cover from baseline monitoring period.

5.4 Determine RUSLE Factors 'R' and 'C'

(Project monitoring period calculations)

For the project monitoring period adjusted ground cover data, determine the 'R' and 'C' factors required for RUSLE calculation.

RUSLE

- R - factor from pluviograph rain
- C - factor from ground cover

Noting that all other RUSLE data modules are downloaded directly from Queensland Government websites and are freely available for public use.

The following equations are used to calculate monthly erosivity 'R', and ground cover factors 'C':

Equation 10 – Storm Rainfall Erosivity ($\boldsymbol{E_l}$)

Using minimum 6-minute interval pluviograph data from the site monitoring station calculate storm (Section 1.5) rainfall erosivity, (Brown & Foster, 1987):

$$\boldsymbol{E_l} = \sum_{k=1}^{n} 0.29[1 - 0.72e^{-0.05I_k}]\Delta t$$

Where:

$\boldsymbol{E_l}$ = Erosivity for storm *l (MJ/ha).*

$\boldsymbol{n}$ = number of time intervals of the storm.

$\boldsymbol{I_k}$ = Rainfall intensity for time interval *k (mm/h).*

$\Delta\boldsymbol{t}$ = Time interval (*h*).

Equation 11 – Monthly Rainfall Erosivity ($\boldsymbol{EI^i_{30}}$)

For month *i*, the rainfall erosivity:

$$\boldsymbol{R^i} = \sum_{l=1}^{n} E_l \boldsymbol{I^l_{30}}$$

Where:

$\boldsymbol{R^i}$ = Erosivity for month *i.*

$\boldsymbol{n}$ = Number of storms in month *i.*

$\boldsymbol{E_l}$ = Rainfall intensity for storm *l.*

$\boldsymbol{I^l_{30}}$ = Maximum 30-minute intensity for storm *l.*

Equation 12 – Monthly C Factor ($\boldsymbol{C_i}$)

RUSLE cover and management factor in month *i* (Rosewell, 1997):

$$\boldsymbol{C_i} = \boldsymbol{e}^{-0.799-(4.74*10^{-2}*(GC_i*100))+(4.49*10^{-4}*(GC_i*100)^2)-(5.2*10^{-6}*(GC_i*100)^3)}$$

Where:

$\boldsymbol{C_i}$ = RUSLE cover and management factor in raw data month *i.*

$\boldsymbol{GC_i}$ = Ground cover proportion in raw data month *i*.

Equation 13 – Baseline C factor using measured ground cover and baseline adjusted ground cover ($\dot{C}_i$)

Creating a C factor adjusted for baseline expected difference in month *i*:

$$\dot{C}_i = \begin{cases} e^{-0.799-(4.74*10^{-2}*(GCA_i*100))+(4.49*10^{-4}*(GCA_i*100)^2)-(5.2*10^{-6}*(GCA_i*100)^3)}, & GCA_i \geq RMGC \\ e^{-0.799-(4.74*10^{-2}(RMGC*100))+(4.49*10^{-4}*(RMGC*100)^2)-(5.2*10^{-6}*(RMGC*100)^3)}, & GCA_i < RMGC \end{cases}$$

Where:

$\dot{C}_i$ = Modelled C factor for raw data month *i.*

GCA_i = Adjusted ground cover proportion for raw data month *i.*

$RMGC$ = The regulated minimum ground cover proportion.

5.5 Relevant pools

(Calculation of change in pollutant entering the Great Barrier Reef)

The relevant pollutant pool is the fine silt and clay fraction (<20 µm) of the sediment delivered to the Great Barrier Reef. The reduction achieved during the monitoring period in FS exports transported to the end of catchment, must be calculated by applying the following equation that uses spatial RUSLE and applies spatial FS proportion and delivery ratio data.

Equation 14 – Calculation of modelled delivery difference – Actual vs. Modelled from baseline projected ground cover ($FSAr$)

$$FSAr = \left(\sum_{i=1}^{n} R^i\ K\ L\ S\ \dot{C}_i\ P\ RF\ FS\ SDR\ CS\right) - \left(\sum_{i=1}^{n} R^i\ K\ L\ S\ \ P\ C_i\ RF\ FS\ SDR\ CS\right)$$

Where:

$FSAr$ = Abatement of FS, in tonnes, to the Great Barrier Reef for monitoring period, r, over the RCAZ.

n = Months in monitoring period.

i = Month.

R^i= Rainfall erosivity at month *i*.

K = Soil erodibility – raster (Refer to Table 1).

L = Slope length – constant raster (Refer to Table 1).

S = Slope steepness – raster (Refer to Table 1).

C_i = Cover management factor, from measured satellite ground cover in month *i.*

$\dot{C}_i$ = Modelled cover management factor, created from measured satellite ground cover in raw data month *i* adjusted with baseline cover adjustment factor from calendar month *j.*

P = Practice factor – constant raster (Refer to Table 1).

RF = Rock Factor – raster (Refer to Table 1).

FS = Fine sediment proportion – raster (Refer to Soil Sampling Plan, 3.4.1).

SDR = Sediment delivery ratio – raster (Refer to Table 1).

CS = Cell area of pixel in hectares (At time of publication: 30m x 30m cell – 0.09ha).

To be eligible for Reef Credits, $FSAr$ must be greater than zero during the monitoring period.

5.6 Accounting for leakage

(Calculation of change in pollutant entering the Great Barrier Reef)

When leakage is considered 'likely', project accounting must include the steps detailed in Section 2.6.

The following equation is used to calculate FS run-off through RUSLE.

Equation 15 – Project Area FS abatement to the reef for the monitoring period accounting for leakage (FSA)

Accounting for likely leakage in Project Areas outside the RCAZ:

$$FSA = \begin{cases} FSAr, & FSAl \leq 0 \\ FSAr - FSAl, & FSAl > 0 \end{cases}$$

Where:

FSA = FS abatement, in tonnes, exported to the Great Barrier Reef for monitoring period, r accounting for leakage.

$FSAr$ = The FS abatement, in tonnes, within the RCAZ.

$FSAl$ = The FS loss, in tonnes, within Project Areas outside the RCAZ (sediment export calculated as per RCAZ reporting method).

5.7 Accounting for disturbance

(Calculation of change in pollutant entering the Great Barrier Reef)

Any natural and unmanageable disturbance, for example: fire originating from a neighbouring property, or cyclone, will impact ground cover and crediting. Project proponents may delay reporting on disturbed areas until site recovery has occurred or exclude affected areas from the project calculations for a period of no more than 12 months.

5.8 Reef Credit Calculation

(Calculation of monitoring period Reef Credits)

Equation 16 – Calculation of Reef Credits (RCr)

To determine the quantity of Reef Credits generated by project activities during the monitoring period, apply the following equation:

$$RCr = \begin{cases} FSAr\ Cf, & Leakage\ not\ considered\ likely \\ FSA\ Cf, & Leakage\ considered\ likely \end{cases}$$

Where:

RCr = Reef Credits generated in monitoring period, *r*.

$FSAr$ = FS abatement, in tonnes, exported to the Great Barrier Reef for monitoring period, *r* for the RCAZ.

FSA = FS abatement, in tonnes, exported to the Great Barrier Reef for monitoring period, *r* accounting for leakage.

Cf = The conversion factor to convert FS abatement to an equivalent Reef Credit as stated in the Reef Credit Standard.

If RCr is zero or less than zero, then no credits are issued for the monitoring period. Note, any negative balance of Reef Credits must then be brought forward to the next reporting period.

5.9 Uncertainty

Estimates of monitoring period FS savings calculated in accordance with this Method are based on reliable remote sensing data. If the approach outlined in this Method is followed, then no confidence deduction is required to account for uncertainty.

6. Monitoring and Record Keeping Requirements

This section sets out monitoring and record-keeping requirements under this Method for a registered Reef Credit Project.

A Monitoring Report must be submitted as a requirement for each monitoring period. The project proponent must document all land management activities, disturbance events that occurred during the monitoring period within the Project Area and monitor the Project Area for continued compliance with the eligibility requirements of the Method (Section 2) and with the GLM Plan (Section 4).

The monitoring report must include (as minimum):

- Measurements of pasture biomass and forage budgets if stated in the GLM Plan; and
- Grazing charts, or similar that demonstrate cattle numbers and their movements and periods of rest (spelling) if stated in the GLM Plan; and
- Records of any other activity stated in the GLM Plan; and
- Disturbance events including polygon shapefiles of the event boundaries; and
- Broadscale clearing event including polygon shapefiles of the event boundaries.

Records must be kept (and provided with each monitoring report) in relation to each of the mapping and data requirements set out in Section 3, including but limited to:

- RCAZ boundaries; and
- Disturbance event boundaries; and
- Soil sampling locations; and
- Rainfall monitoring location/s, records, initial calibration, and verification.

7. References

Bastin, G., Scarth, P., Chewings, V., Sparrow, A., Denham, R., Schmidt, M., O'Reagain, P., Shepherd, R., & Abbott, B. (2012). Separating grazing and rainfall effects at regional scale using remote sensing imagery: A dynamic reference-cover method. *Remote Sensing of Environment*, *121*, 443-457. https://doi.org/10.1016/j.rse.2012.02.021

Brown, L. C., & Foster, G. R. (1987). Storm erosivity using idealized intensity distributions. *Transactions of the ASABE*, *30*, 379-386. https://doi.org/10.13031/2013.31957

Renard, K. G., Foster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1997). *Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE)*. United States Government Printing Office.

Rosewell, C. J. (1997). *Potential sources of sediments and nutrients: Sheet and rill erosion and phosphorus sources.* Australia: State of the Environment Technical Paper Series (Inland Waters). Department of the Environment, Sport and Territories.

Wischmeier, W. H., & Smith, D. D. (1978). *Predicting rainfall erosion losses: A guide to conservation planning (USDA Agricultural Handbook No. 537)*. United States Department of Agriculture.

Yu, B. (1998). Rainfall erosivity and its estimation for Australia's tropics. *Australian Journal of Soil Research, 36*(1), 143-165. https://doi.org/10.1071/S97025