Project title: Namibia Integrated Landscape Approach for enhancing Livelihoods and Environmental Governance to eradicate poverty (NILALEG)		
GEF Implementing Agency : United Nations Development Programme		
Country: Republic of Namibia	**Implementing Partner:** Ministry of Environment and Tourism	**Management Arrangements:** National Implementation Modality (NIM)
UNDP-GEF PIMS ID number: 5640	**GEF ID number:** 9426	

Annex B(ii) Results of the calculations on the net avoided emissions

Results of the calculations on the net avoided emissions

R.S. Bhalla

Introduction

An analysis of land use and trends in deforestation degradation was used to parametrise the FAO EX-Ante Carbon-balance Tool (EX-ACT) and to arrive at alternative measurements based on an analysis of satellite images and products, particularly, long term means and trends in the normalised difference vegetation index (NDVI) and net primary productivity (NPP). Data used here was derived from existing spatial datasets hosted by the Namibia Statistics Agency and sourced from a variety of government projects and programmes, chiefly the Atlas of Namibia. LANDSAT and MODIS images were analysed on the Google Earth Engine[1].

The primary purpose of this analysis was to arrive at recent trends in forest/vegetation loss and estimates of primary productivity and land-cover change. This data also served to validate the results from the EX-ACT tool.

This document explains how the EX-ACT tool was parametrised, and the calculations used to derive the independent measures of NPP using satellite imagery. We used conservative estimates of productivity and expected impacts of project interventions.

Evidence of land cover change

Analysis of Normalised Difference Vegetation Index (NDVI)

Based on trends in NDVI[2] in the focal landscapes we estimate the annual rates of land cover change in classes relevant to this project, namely forests, scrub or bush, rangelands and degraded lands. We used FAO-based values of NDVI for land cover classes[3]. These are approximations of on-ground conditions and an accuracy matrix of the results could not be produced due to lack of ground control points. Moreover, there is a probable overlap between the adjacent land cover types, i.e. degraded forest and scrub, and degraded scrub and rangeland. The cut-off values used were:

1 > Forest > 0.4 > Scrub > 0.25 > Rangeland> 0.13 > Degraded land > 0 Moist soils and water > -1.

Area under different land cover types was then calculated.

1 Scripts used for the analysis can be accessed from <https://gitlab.com/rsbhalla/nilaleg/tree/master>.

2 Yengoh, Genesis T, David Dent, Lennart Olsson, Anna E Tengberg, and Compton J Tucker. ‘The Use of the Normalized Difference Vegetation Index (NDVI) to Assess Land Degradation at Multiple Scales: A Review of the Current Status, Future Trends, and Practical Considerations’. Lund University Center for Sustainability Studies (LUCSUS): Lund University Center for Sustainability Studies (LUCSUS), and The Scientific and Technical Advisory Panel of the Global Environment Facility (STAP/GEF)., 2014.

3 Based on: Meneses-Tovar, C L. ‘NDVI as Indicator of Degradation’. Unasylva 62, no. 238, (February 2011): 8.

Focal Landscape	Forest		Scrub		Rangeland		Other		
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Total
Omaoipanga	23	0.01	56,051	27.86	144,858	72.01	243	0.12	201,175
Ruacana	748	0.68	76,156	69.38	32,788	29.87	76	0.07	109,768
Omauni Okongo	7,600	5.81	100,539	76.84	22,700	17.35	0	0.00	130,838
Nkulivere	4,302	2.17	163,208	82.35	30,683	15.48	0	0.00	198,193
Zambezi	34,578	15.77	152,418	69.50	29,769	13.57	2,540	1.16	219,306
Total	47,251	5.50	548,372	63.82	260,798	30.35	2,860	0.33	859,280

The trends averaged over the five focal landscapes were also estimated for the period between 2003 and 2018 (sixteen years)

Cover	% Trend
Forest	0.81%
Scrub	0.76%
Rangeland	-0.36%
Degraded	-1.35%
Moist soils and water	-2.32%

When broken down into the different focal landscape the following trends emerge.

Cover	Omaoipanga	Ruacana	Okongo	Nkulivere	Zambezi
Forest	-0.37%	0.06%	0.65%	0.87%	0.86%
Scrub	-0.85%	-0.23%	0.94%	1.29%	1.16%
Rangeland	-1.18%	-0.61%	0.66%	1.14%	1.27%
Degraded	-1.04%	-0.24%	-1.25%	0.80%	-2.09%
Moist soils and water	-0.32%	-0.05%	0.00%	0.00%	-2.42%

Omaiopanga stands out in showing decreasing trends in both forests and rangelands and almost a flat and slightly increasing (but still in the negative) trend in scrub or bush. This landscape clearly needs most attention as the graph suggests that thicker the forest greater its loss.

Ruacana shows very clear signs of degradation in all land cover classes, except forests which show a positive trend increasing towards higher NDVIs (denser forests). A good case for prioritising forest conservation.

All land cover types in Okongo show an increasing trend with increasing NDVI; however, over half the region under rangelands show a negative trend while rangelands in the upper NDVIs show an slight increase. This increase could well be due to bush encroachment. Scrub or bush is showing a gradual increase as well while forests are essentially 'flat', showing very marginal gains as NDVI increases.

Nkulivere shows a very slowly increasing trend for all cover types moving positively with higher NDVIs in each cover class. However, degraded areas seem to show removal of vegetation, wherever it exists which could be a sign of overgrazing.

Zambezi is an inherently more productive focal landscape; however, degraded areas are getting further denuded, particularly those with little vegetation to start with. Both rangelands and scrub are showing a very small increasing trend which doesn't change its slope with increasing NDVIs. Dense forests, however, seem to be increasing at a faster rate than sparse forests with lower NDVIs.

Analysis of Net Primary Productivity (NPP)

Results of the NDVI were further supported by an analysis of trends in net primary productivity which is a proxy for carbon sequestered annually. We used mean NPP rates and trends for a period of fifteen years. Our results show a consistent rate of decrease in NPP in all the focal landscapes. We repeated this analysis for the most recent three years that the data was available i.e. 2011 to 2013 and 2012 to 2014. Interestingly, the trend for the years 2012 to 2014 was positive. This was probably because 2014 was an unusually rainy year; however, it also goes to show that given adequate moisture, these trends can be reversed[4].

ID	Focal Landscape	Trend 2000 - 2014	Trend 2011 - 2013	Trend 2012 - 2014
1	Omaoipanga	-0.17	-0.83	0.08
2	Ruacana	-0.21	-1.42	0.21
3	Omauni Okongo	-0.20	-1.65	0.00
4	Nkulivere	-0.17	-1.54	0.07
5	Zambezi	-0.25	-0.63	0.43

The trend of loss in NPP has increase alarmingly in all focal landscapes. Even though no data was available for the past five years, given the recent field observations on the rates of deforestation, these trends have probably become even more negative in the focal landscapes.

Analysis of mean NPP was also quite revealing. The mean annual NPP in year 2000-2001 was substantially higher than the mean NPP and more than twice that of the latter years suggesting a continuous removal of vegetation which has increased in the latter years. While we do not have NPP data for the more recent period, this suggests an alarming loss of forests and productive vegetation in the focal landscapes.

4 A more sophisticated trend analysis would incorporate the effects of rainfall and temperature, however this was not possible in the time available.

Focal Landscape	2000 - 2014	2000 - 2001	2012 - 2013	2013 - 2014
Omaoipanga	2.81	4.30	1.65	1.72
Ruacana	3.61	5.32	1.90	2.11
Okongo	4.62	6.63	2.88	2.88
Nkulivere	4.22	6.19	2.71	2.78
Zambezi	5.13	8.79	3.71	4.15

Justification for values used to estimate NPP and parametrise the EX-ACT tool

Given these observations we make the following assumptions for the values used to parametrise the EX-ACT tool (see appendix for screen grabs).

Based on field experience we know that the greatest rate of forest loss in the recent past was in the Okongo focal landscape. This is borne out by the recent NPP trends. We also observed from the NDVI figures that the large proportion of area under bush or scrub is in Nkulivere and the largest under rangelands or grasslands is in Omaiopanga. We therefore used their respective rates of NPP change as an index of degradation. Thus:

- Present grassland productivity was taken from the measured mean NPP (in mega grams of carbon per hectare per year, or Mg C ha^{-1} y^{-1} from Omaoipanga focal landscape, which is a grassland dominated, during 2011/2013 (1.65 Mg C ha^{-1} y^{-1}). The potential productivity for grasslands was taken from the mean productivity of during 2001-2001 (4.30 Mg C ha^{-1} y^{-1}).
- Values of trends in NPP for forest areas were taken from Okongo for the period 2011/2013 (-1.65 Mg C ha^{-1} y^{-1}). Okongo has the second highest proportion of forests forest among the focal landscapes. Further, it is the focal landscape where forest degradation has been observed to be the highest. Furthermore, the NPP values of Zambezi, which has the highest proportion of forests, are probably higher due to the rapid re-growth of bush owing to favourable growing conditions.
- Values for trends in NPP for scrub were taken from Nkulivere (-1.54 Mg C ha^{-1} y^{-1}) which has the highest proportion of scrub among the focal landscapes.
- Under management, the total of 18,000 ha for forests to be protected was listed.
- 3,000 ha under land use and land cover change was listed under forests and another 3,000 for bush thinning.
- A total of 17,000 ha was listed under grasslands corresponding to restoration and sustainable rangeland management.

The proposed areas for different interventions for the project are as follows. These figures were used to populate the EX-ACT tool as indicated in the footnotes.

Activity	Forests restored (ha)	Grasslands restored (ha)	Forests protected (ha)	Grasslands protected (ha)
Regional Forest Reserve established in 10,000 ha leading to their sustainable management and restoration.			10,000[5]	
Forest policy implemented in 3,00 ha of community forests leading to sustainable management and restoration.			3,000[6]	
Restoration of savannah and forests in 10,000 ha.	3,000[7]	7,000[8]		
Agroforestry and sustainable crop/rangeland management in 15,000 ha.			5,000[9]	10,000[10]
Bush thinning in 3,000 ha.		3,000[11]		
Totals	3,000	10,000	18,000	10,000

NPP based estimates

In order to estimate the NPP of restored landscapes we assumed a modest 10% rate of increase in NPP per year. We calculated the increase in NPP over twenty years based on these values to estimate the scenarios as presented below:

Scenario without project	Scenario with project
A. 10,000 hectares of woodland and savannah already in poor condition continues to be degraded, e.g. • 3000 ha of forests with a NPP lost @ -1.65 over 20 years. This amounts to about 32.48% of the total NPP in 20 years. **98,770.03 Mg C ha^{-1}.** • 7,000 ha grazing land currently with scrubby vegetation expected to be overgrazed and denuded of palatable species and eroded over 20 years. NPP lost @ -0.83 per year and 23.12% over 20 years: **116,666.69 Mg C ha^{-1}.**	A. 10,000 hectares of woodland and savannah is restored @ 10% per year. • Forest degradation arrested and restoration done in 3,000 ha. NPP gained from preventing degradation (column on left) plus NPP gained from restoration (10% per year over 20 years): 98,770.03 + 30,411.56 = **12,9181.59 Mg C ha^{-1}.** • 7,000 ha of rangeland denudation arrested plus gains from restoration of rangelands over 20 years at 10% per year: 116,666.69+50,457.11 = **167,123.80 Mg C ha^{-1}.**
B. 3,000 hectares in Community Forests currently semi pristine but very poorly managed, forest slowly	B. 3,000 hectares better managed in Community Forests through effective protection and

5 EXACT Sheet 5.Management: Row 13
6 EXACT Sheet 5.Management: Row 14
7 EXACT Sheet 2.LUC: Row 31
8 EXACT Sheet 4.Grassland: Row 22
9 EXACT Sheet 5.Management: Row 15
10 EXACT Sheet 4.Grassland: Row 23
11 EXACT Sheet 2.LUC: Row 49

lost over 20 years till all is under crops except 20% which is thinned and degraded. NPP lost @ -1.65 over 20 years. This amounts to about 32.48% of the total NPP in 20 years. **98,770.03 Mg C ha^{-1}.**	implementation of management plans, and enriched with planting of useful species harvested sustainably over 20 years. Arresting degradation plus restoration @ 10% per year of NPP 98,770.03 + 30,411.56 = **129,181.59 Mg C ha^{-1}.**
C. 15,000 hectares currently under communal free for all and in moderate conditions but degrading / being lost to crops at the rate of -1.65 Mg C/ha for forests and -0.83 for grasslands. • 5,000 ha forest (after 20 years 32.48% NPP lost due to removal of large trees): **164,616.72 Mg C ha^{-1}.** • 10,000 ha grazing land currently with scrubby vegetation is totally overgrazed and denuded of palatable species, gets eroded over 20 years 23.12% NPP lost): **166,666.71 Mg C ha^{-1}.**	C. 15,000 hectares under new sustainable crop/ rangeland management or agroforestry • 5,000 ha of forests prevented from degrading, sustainably managed and restored adding 10% NPP per year for 20 years: **164,616.72 + 50685.93 = 215,302.64 Mg C ha^{-1}.** • 10,000 ha of rangelands prevented from degradation and restored and sustainably managed over 20 years adding 10% NPP per year. **166,666.71 + 72081.58 = 238,748.29 Mg C ha^{-1}.**
D. 10,000 hectares currently relatively pristine but under communal tenure with no control - forest slowly lost over 20 years till all is under crops except 20% which is thinned and degraded. 32.48% NPP loss over 20 years @ -1.65 per year. **329,233.43 Mg C ha^{-1}.**	D. 10,000 hectares (and biodiversity therein) protected through establishment of Regional Forest Reserve. Area effectively protected consequently arresting degradation. Effective community-based management and sustainable harvesting over 20 years leading to 10% increase in NPP per year. **329,233.43 + 101,371.85 = 430,605.29 Mg C ha^{-1}.**
E. 3,000 hectares of rangelands encroached by bush making it unavailable for grazing and productive use and with negative affects on water and the economy as a whole. Furthermore, bush encroached rangelands are a serious fire risk and these fires typically result in the release of the bulk of above ground carbon into the atmosphere.	E. 3,000 hectares of encroacher bush thinned leading to an increase in herbaceous biomass, increased availability of rangelands for productive use, increased availability of water and reduced risk of fire.
As discussed in the proposal document, removal of bush encroachment may yield a net increase in carbon sequestration if grasses and other herbaceous biomass are allowed and encouraged to establish themselves. However, there is a lack of data, particularly from the northern parts of Namibia on the carbon consequence of removal of bush. Consequently, this intervention is being considered carbon neutral for the independent calculations for carbon sequestration, however is being included in the EX-ACT tool.	
Total loss of NPP without interventions: **974,723.61 Mg C ha^{-1}.**	Total gain of NPP with arrest of degradation and restoration/management interventions: **1,310,143.19 Mg C ha^{-1}.**

Using these calculations, we estimated that the project would result in a total gain of 1,310,143.19 mega-grames (tonnes) of carbon per hectare over a twenty-year period. This, for a total area of 41,000 hectares over 20 years amounts to a net increase of 1.6 mega-grams per hectare per year.

The estimates using the EX-ACT tool were a net gain of 1,368,445 mega-grams of carbon per hectare with 36.4% of uncertainty. The amounts to an increase of 1.67 mega-grames per hectare per year.

Implications for Monitoring Carbon Benefits

The procedure and results described above provide a basic framework for satellite imagery based monitoring of carbon sequestration, in terms of net primary productivity. Most of this analysis can be automated on cloud-based computing frameworks such as the Google Earth Engine or other subscription based alternatives. There are some caveats to the methods which ought to be addressed if this is to be developed into a formal monitoring framework.

1. More recent datasets for NPP need to be utilised. There are many remotely sensed indices which can be explored if the MODIS products are not brought on-line. Products based on LANDSAT or SENTINEL imagery would have the added advantage of better resolution and will allow easier ground validation.

2. Trends in NPP used for this analysis need to be improved upon by removing the influence of rainfall and temperature (de-trending). This will provide a more accurate estimate of NPP trends.

3. Non-linear regressions will improve the predictive ability of the model and should be utilised in place of the linear model used here. Furthermore, the adjusted R^2 and p-values of the model should be used to determine how reliable the model is.

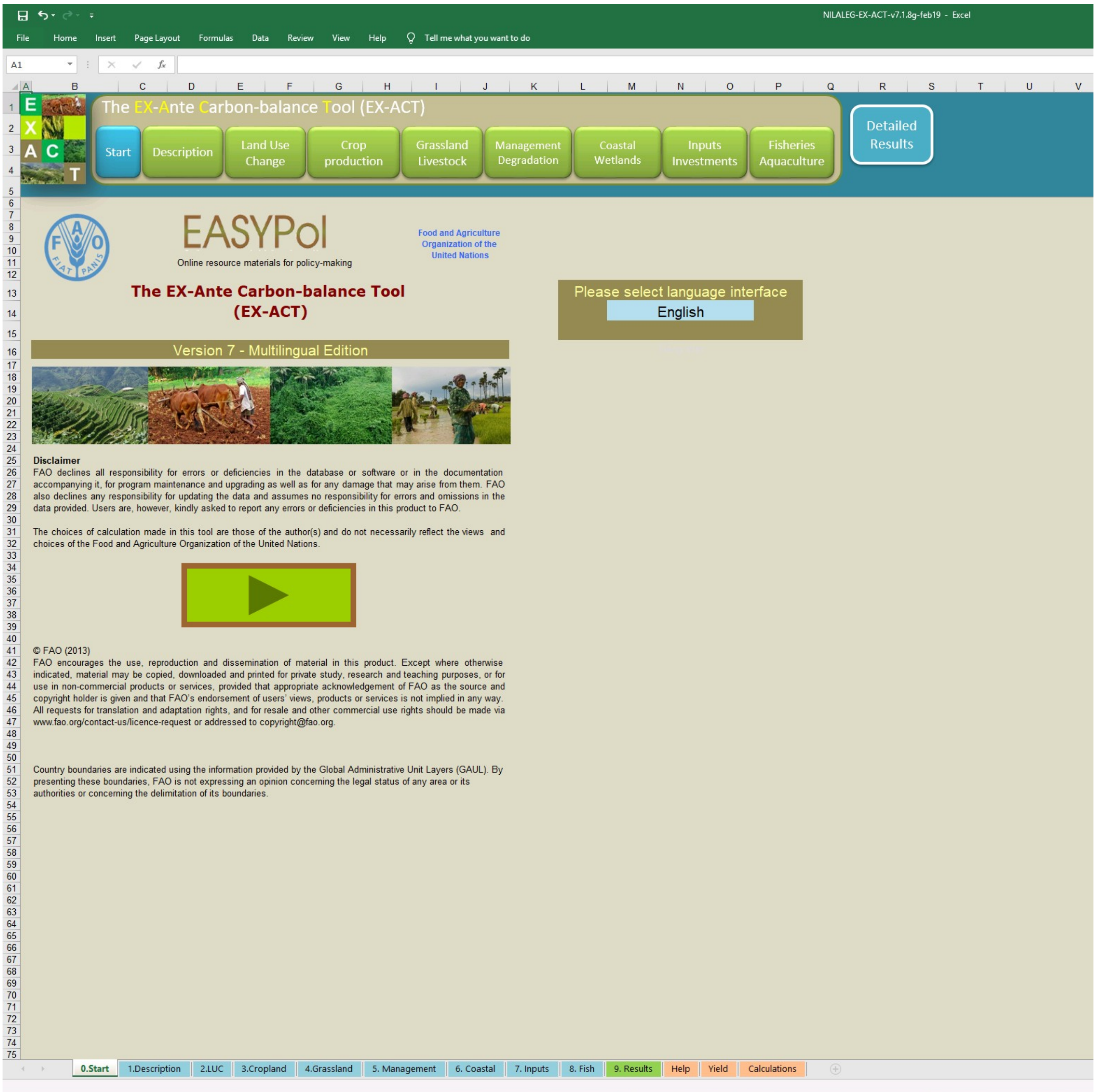
4. Actual rates of recovery and restoration need to be based on ground measurements of biomass accumulation. This is a non-trivial activity and would involve setting up of long-term monitoring plots in representative land cover across the focal landscapes. Ideally, this would be done in collaboration with other projects seeking to establish and report on Namibia's achievements of its LDN commitments.

5. Collaborations with other projects investigating the carbon storage consequence of bush encroachment and its removal with herbaceous species will provide an important source of data on the likely impact of NILALEG in regards to such interventions.

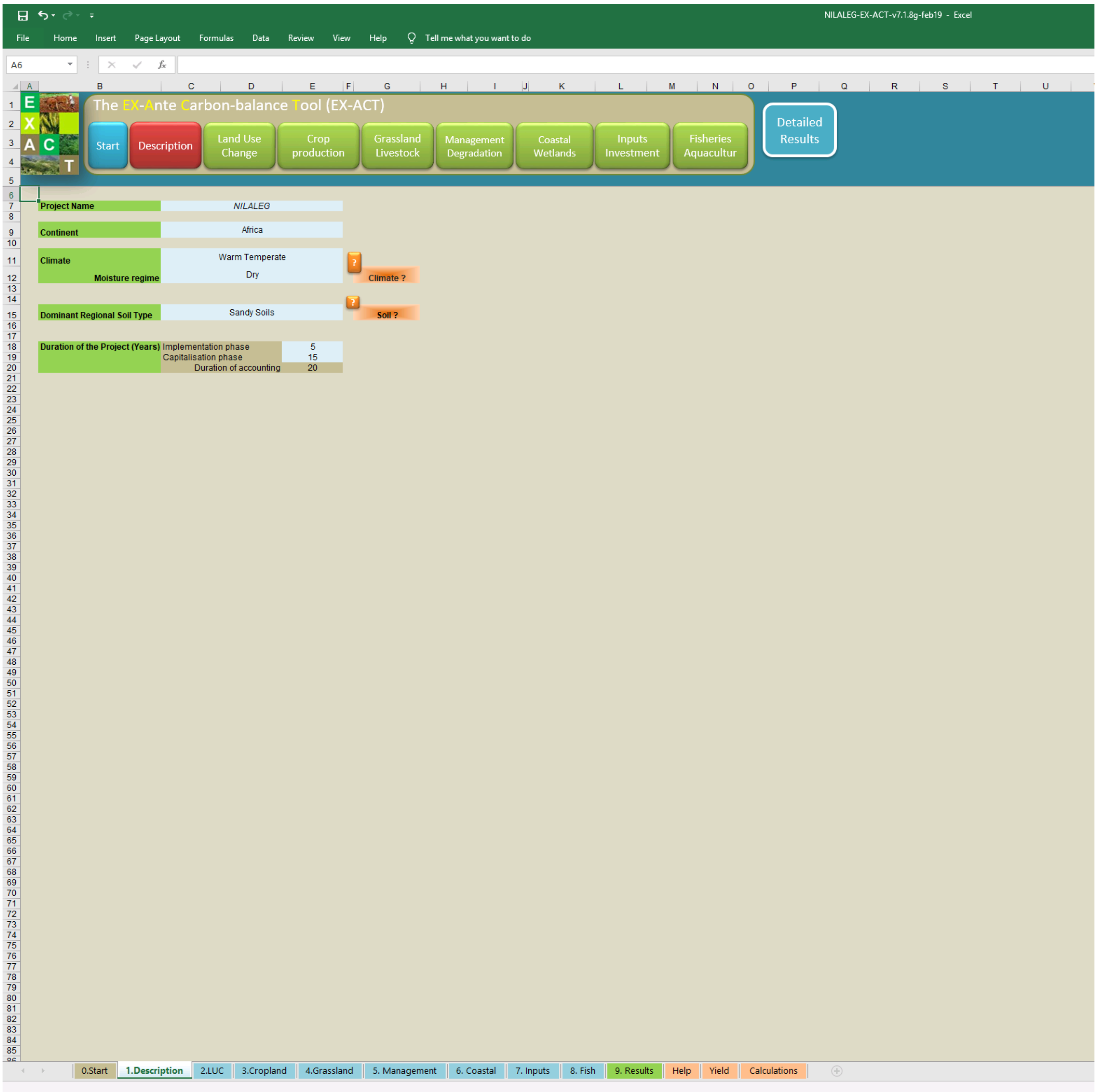
Appendices

Screen grabs of relevant pages from the EX-ACT tool.

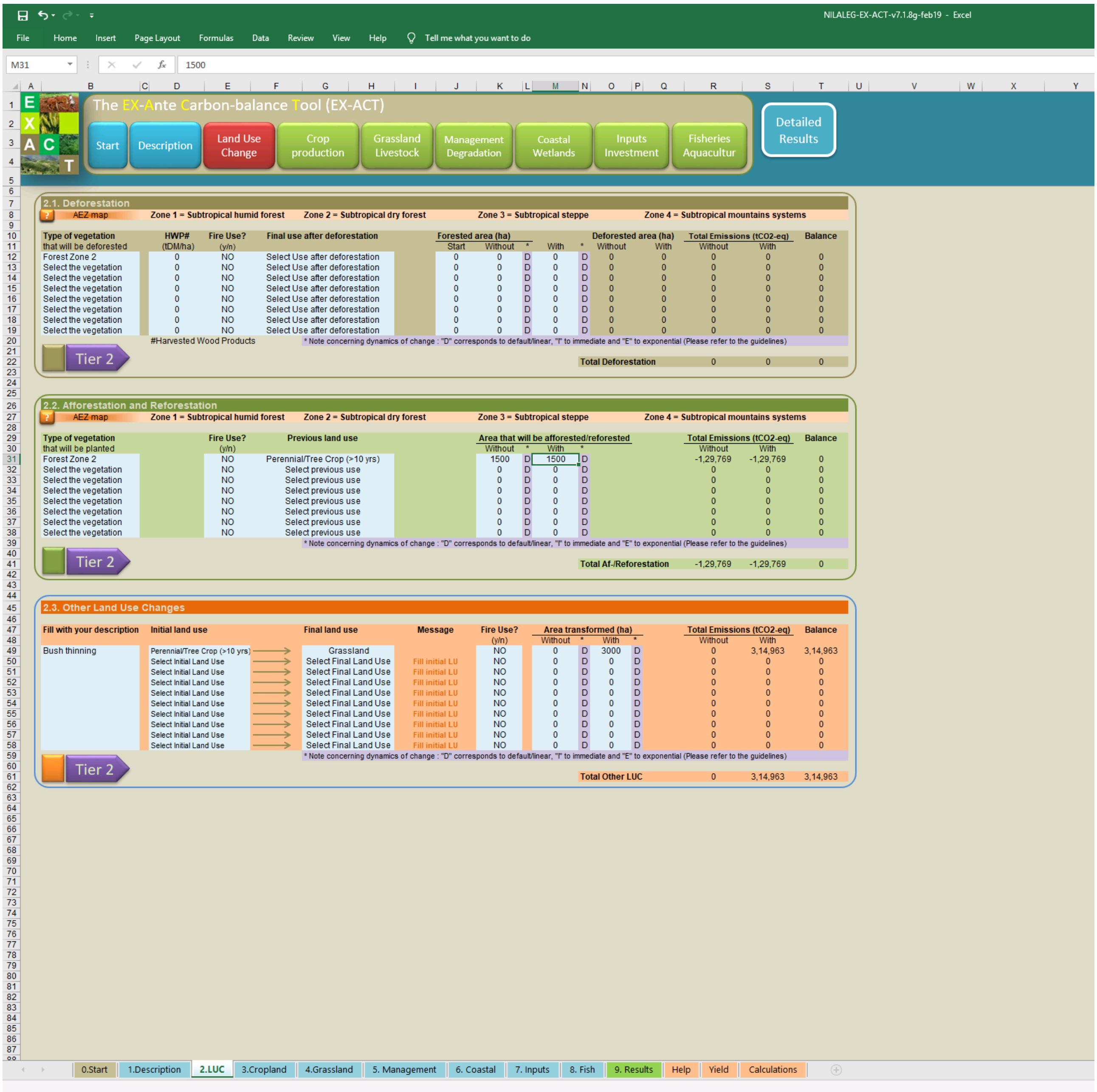
Start. Page 0.



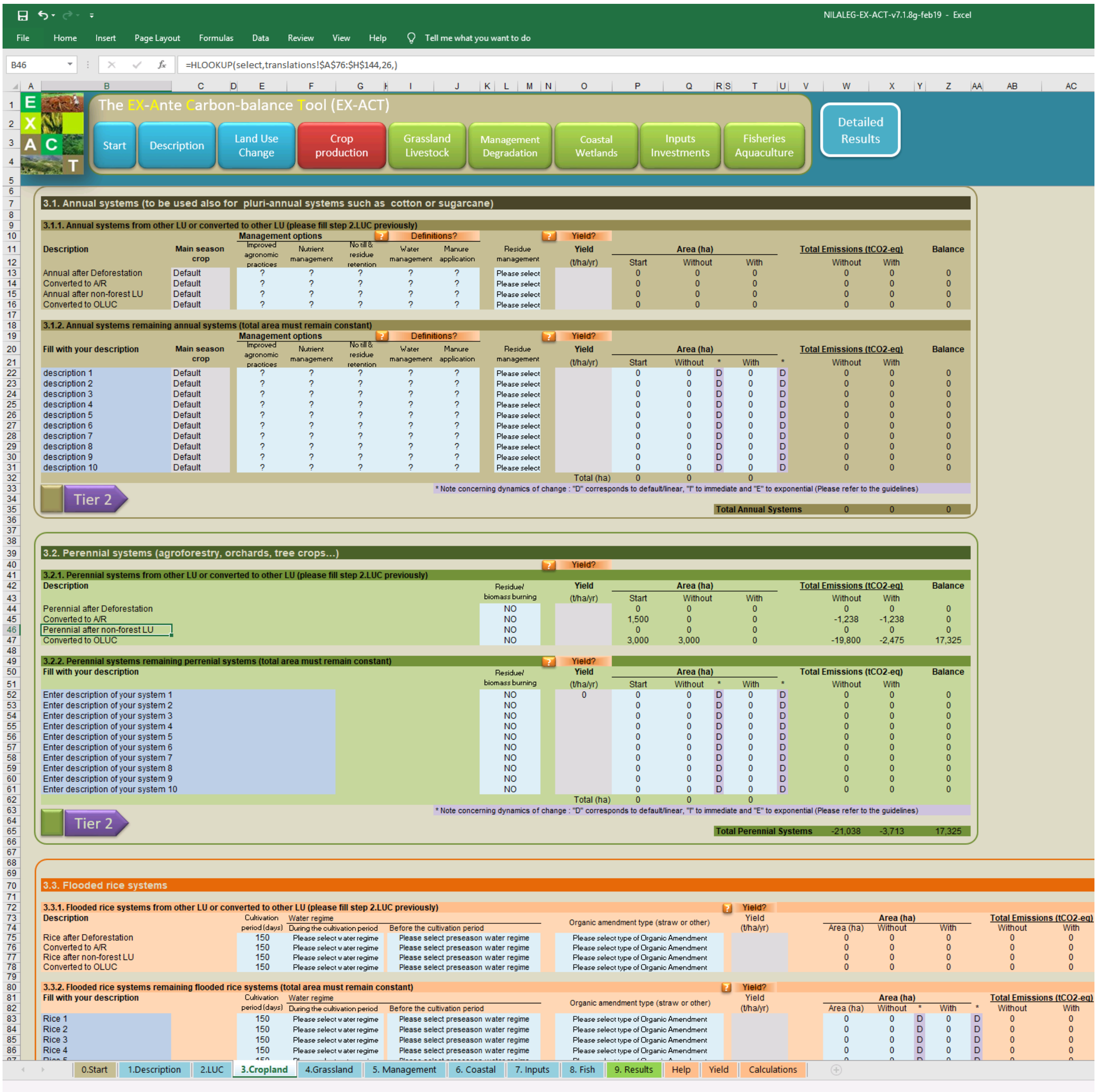
Description. Page 1.



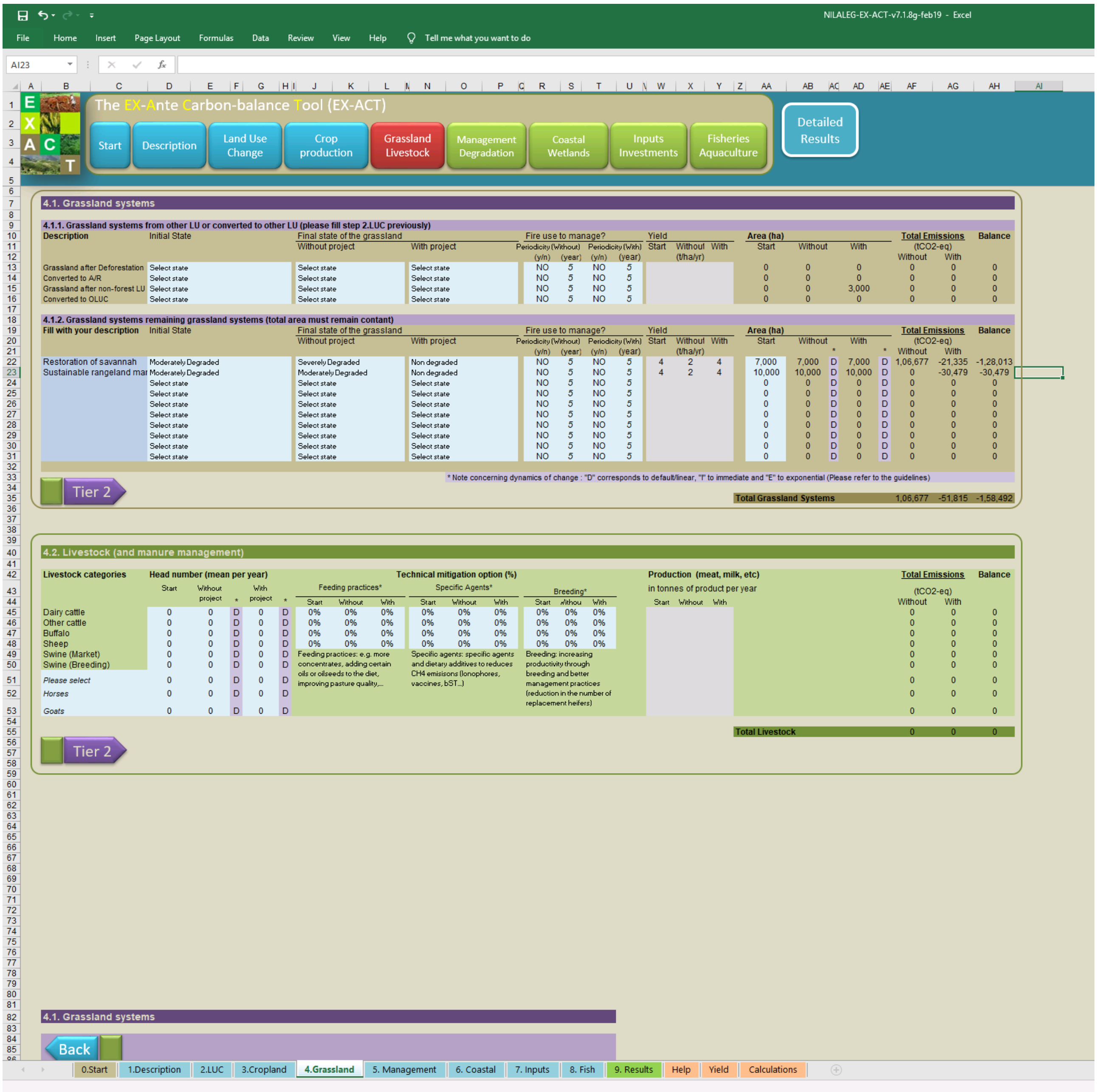
Land use change. Page 2.



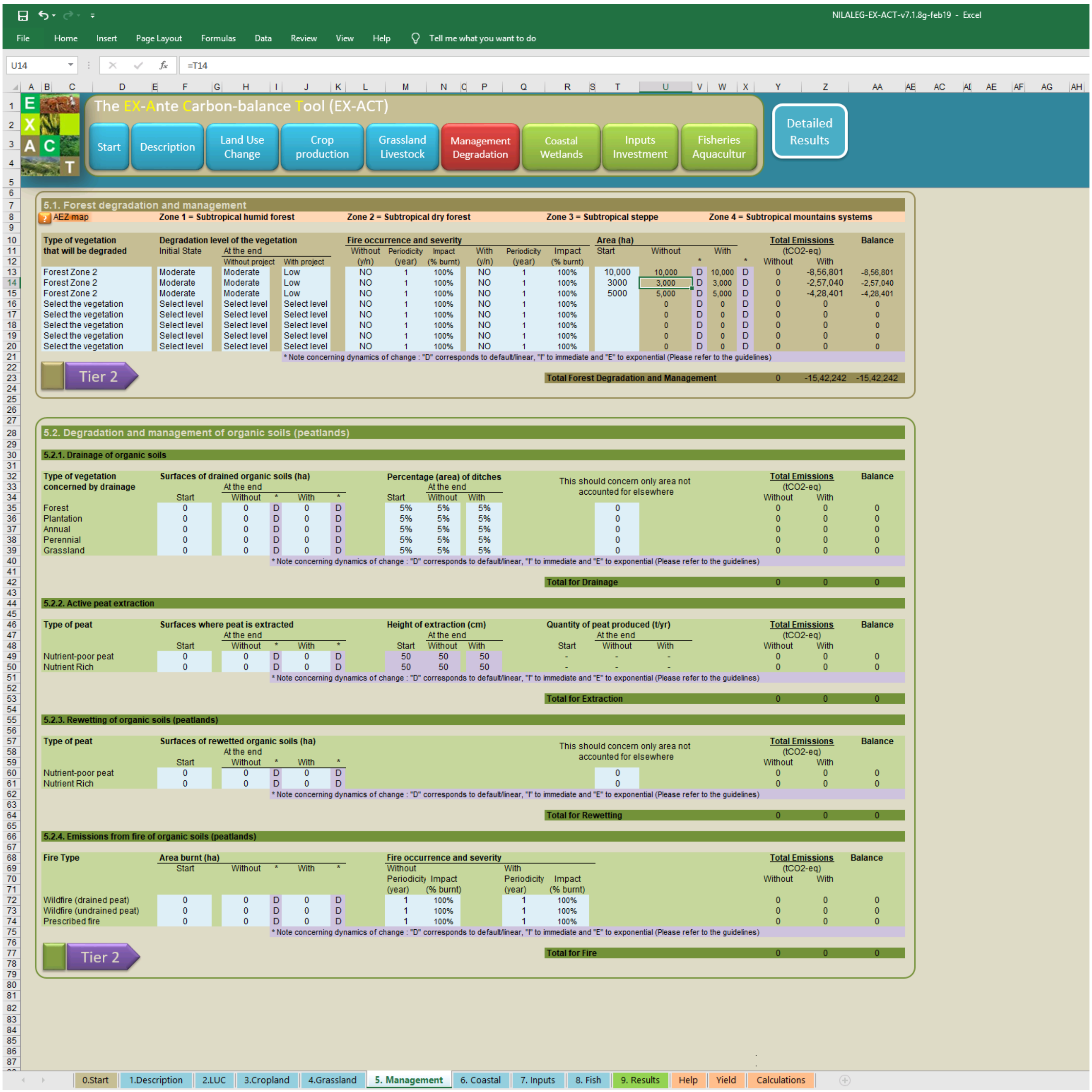
Cropland. Page 3.



Grassland. Page 4.



Management. Page 5.



Results. Page 9.