Mount Elgon Tree Growing Enterprise Ltd

The Mbale Trees Programme

A review of tree coverage in the Mbale region using satellite imagery analysis

Size of Wales Maint Cymru

Llywodraeth Cymru Welsh Government

Contents

The Mbale Trees Programme: A review of tree coverage in the Mbale region using satellite imagery analysis

Abstract:
Launched in 2008, The Mbale Trees Programme, a partnership between the Welsh Government, Size of Wales and the Mount Elgon Tree Growing Enterprise (METGE), has aimed to increase tree coverage in an area of eastern Uganda by providing free tree seedlings to local communities. In this report, the Office of National Statistics - Foreign Commonwealth Development Office (ONS – FCDO) with support from the Welsh Government (WG) used Sentinel-2 satellite imagery to determine whether there has been a change in tree coverage in the Mbale Trees Programme area between 2016 and 2022.

Since trees from the programme are usually planted individually or sparsely in a large area as agro-forestry systems, it was not possible to link specific changes in tree coverage directly to the Mbale Trees Programme due to the resolution of the imagery. However, when analysing tree canopy change in the programme area, there is a net gain in tree cover of 35m^2 per hectare within 5km of nurseries, but a net loss of trees, of 5m^2 per hectare further than 5km from METGE nursery sites. This means that tree gain within 5km of METGE nursery sites is 7 times higher than further away, as identified from satellite imagery analysis. Replicating the analysis across sub-counties, there is also a clear pattern of significant net tree cover gain in sub-counties with one of more METGE nurseries present. This report therefore concludes that the Mbale Trees Programme is likely having a significant positive influence on the tree cover across the implementation area in eastern Uganda.

Introduction:
The Mount Elgon region of eastern Uganda is a hilly, heavily deforested area with a rapidly growing population of around 4% annually (UBOS, 2022). The Mbale Tree Programme area is within this region and is shown in Figure 1 as an area within the east of Uganda, denoted by the red line.

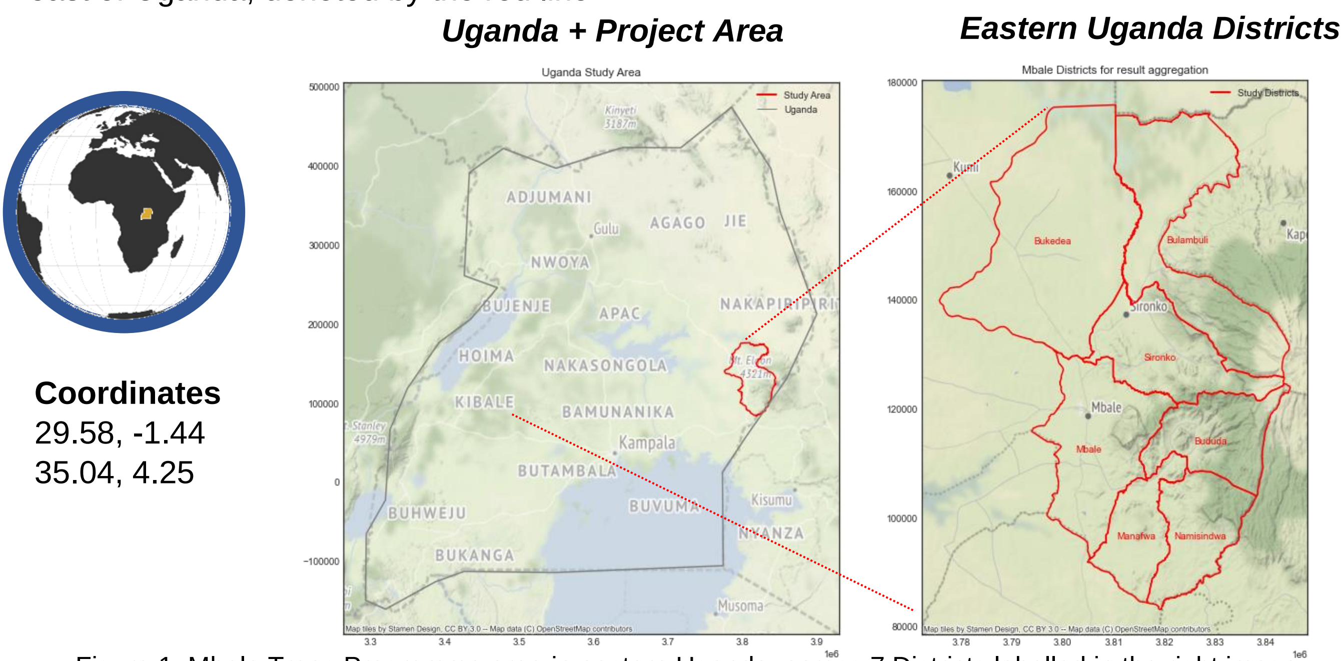


Figure 1: Mbale Trees Programme area in eastern Uganda, across 7 Districts labelled in the right image

The Mbale Trees Programme is an initiative between the Welsh Government, Size of Wales and the Mount Elgon Tree Growing Enterprise (METGE). The programme works in collaboration with local partners to freely distribute tree seedlings to local people for planting on smallholdings or community land. The programme also links with the Welsh Government's Plant! scheme, where two trees are planted for every child born or adopted in Wales - one in Uganda and one in Wales.

The Mbale Trees Programme aims to increase tree coverage in this area of eastern Uganda, distributing over 50 different tree and shrub species, 40% of which are indigenous to the area. These trees have several benefits: producing fruit for consumption or sale, providing medicine, proving shade and shelter for crops schools and farmsteads, reducing logging pressure, providing a sustainable source of fuel wood, stabilising slopes, and providing forage for bees and other pollinators. The programme also promotes and funds the building of Lorena fuel efficient stoves, which can use up to 70% less fuel wood than the conventional 3 stone fires, which aims to reduce logging pressure and primary deforestation in the region.

From 2009 to 2022, more than 18 million trees have been distributed through the programme to local communities. All seedlings are distributed from a network of community run tree nurseries, collected by the land owner and then transported, often on foot or bicycle to their planting site. The study site for the image analysis, as well as the location of tree nurseries included in analysis are shown in Figure 2.

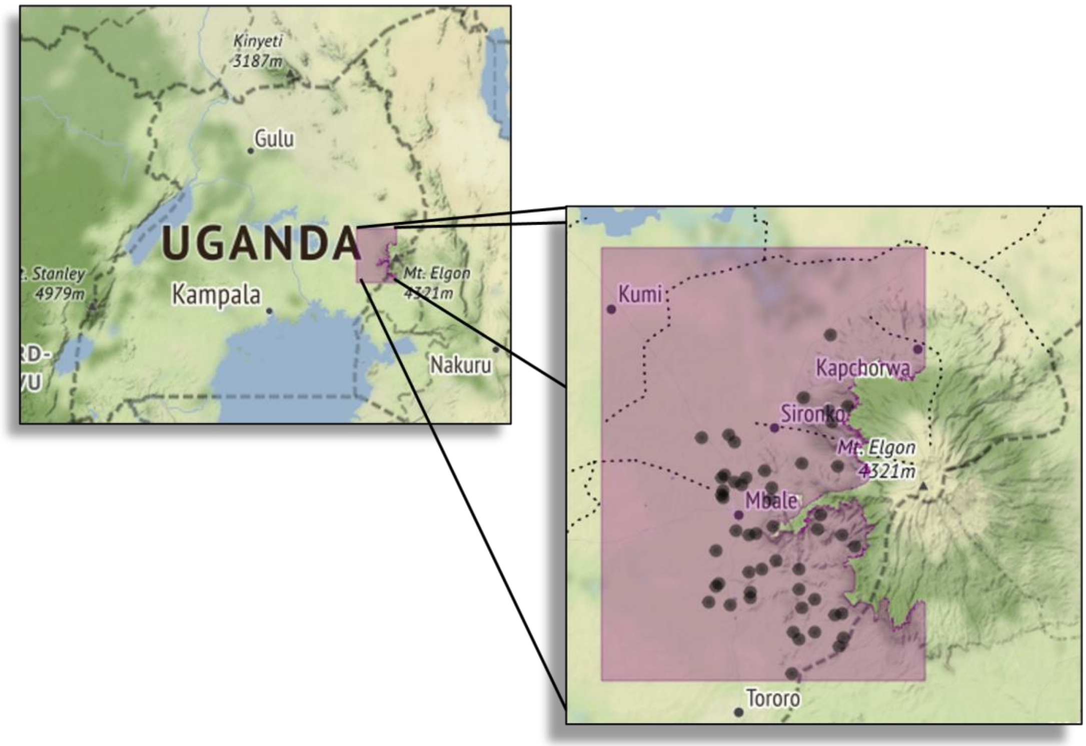


Figure 2: Tree nurseries which distribute seedlings shown as black circles, and the area for image analysis shown in purple – excluding the area of Mount Elgon National Park.

The photographs in Figure 3 (A-B) show typical community nurseries where trees are distributed from. Most nurseries have an annual target to distribute 60,000 trees, though around 30% are ‘Super Nurseries’ distributing double that. This brings the total cumulative distribution across the programme to 3.2 million trees per year. The trees are usually planted in agroforestry systems as crop shade, shown in Figure 3 (C-D).

Figure 3: (A) Makunya women’s community nursery watering seedlings. (B) Farmers attend Bumayoka nursery to take seedlings which are logged by the operator for surveying once established. (C) Mango trees shade coffee, matooke, and bean crops. (D) Agroforestry – maize planted under mango and acacia trees.

Methods

The Welsh Government asked the Foreign, Commonwealth and Development Office Hub, which is part of the Office of National Statistics’ Data Science Campus (ONS-FCDO Hub) to help analyse the impact of the Mbale Trees Programme. The ONS-FCDO Hub focused on developing a process that would be open-source, reproducible, and accessible to others. Therefore, Sentinel imagery, and python coding were used to conduct this analysis.

Area of Interest

Within the east of Uganda, METGE tree nursery sites are located within 7 Districts as shown in Figure 4: Bududa, Bukedea, Bulambuli, Manafwa, Mbale, Namisindwa, and Sironko.

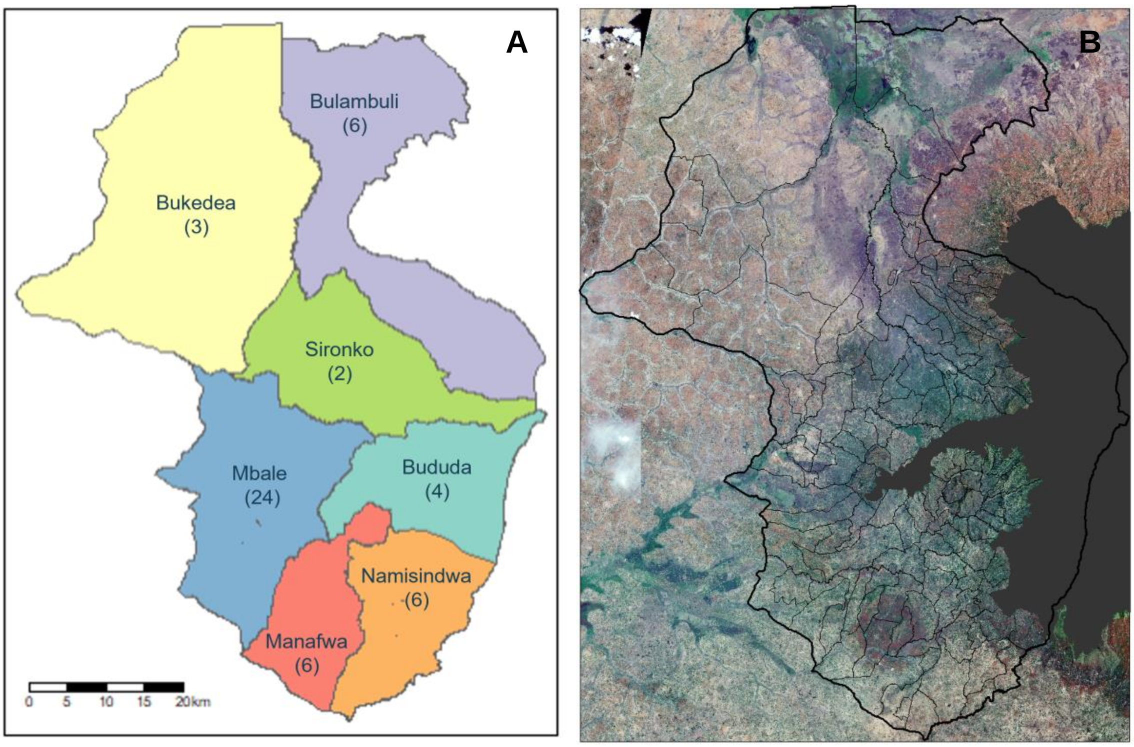


Figure 4: (A) Districts within the Mbale Trees Programme area, with number of METGE nurseries per District shown in brackets (B) Sentinel 2 true colour image overlaid with sub-county outlines, with the Mount Elgon National Park analysis exclusion area marked in grey in the east of the image.

Imagery was downloaded to cover the entire region of interest which covers the 7 Districts in 1 image swath (Figure 4B). In the far east of the region, Mount Elgon National Park rises steeply from the surrounding area. This area was excluded from the analysis as shown by the grey area in Figure 4B, since the Mbale Trees Programme does not operate in this area.

The National Park was also excluded since it has steep and rocky terrain, creating significant shadow in the image, as well as creating frequent heavy cloud due to the mountainous terrain. These artifacts would require additional image-processing and given there is no community planting from the Mbale Trees Programme within the National Park, it was decided to exclude the area from analysis.

Imagery

The European Space Agency (ESA)'s Copernicus suite of satellites were chosen as a suitable compromise on temporal and spatial resolution, which are freely downloadable. Sentinel 2A was launched in June 2015, and 2B in February 2017.

Sentinel-2 is a multi-spectral satellite that captures visible, near infrared and short-wave infrared light across a swath of 290km. Visible (blue, green, red) and near infrared light are captured at a resolution of 10 meters. This means one pixel on the image represents 10m on the ground. Short-wave infrared is captured at 20m resolution. At 10m resolution the crowns of individual trees are not visible, but groups of trees can be effectively detected. New imagery is available every 5 days, though optical data is influenced by cloud cover and so this temporal resolution is effectively significantly reduced.

Although the Mbale Trees Programme started in 2008, there is no suitable available Sentinel imagery across the programme area until 2016. Imagery from the dry season was selected to minimise the risk of over or mis-classification from crops such as rice, and the longest time period available with cloud free imagery for comparison was February 2016 – January 2022. A snapshot of these images is shown in Figure 5.

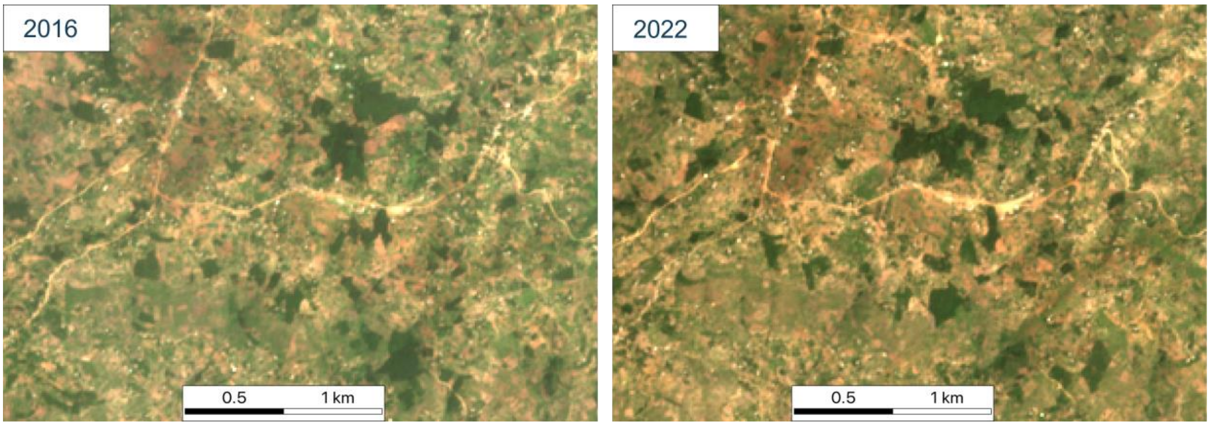


Figure 5: True colour (red, green, blue) clips of chosen Sentinel-2 images in the Mbale District from February 2016 (left) and January 2022 (right), showing groups of trees in dark green.

Tree detection algorithm

The spatial resolution of Sentinel-2 satellite imagery (10m) means that only areas of trees can be identified, as opposed to single, or dispersed tree canopies. A minimum of 3 adjacent pixels is generally recognised as the minimum area with a similar spectral signature needed to ensure accurate land cover identification. This means that 30m on the ground would be the minimum area that a precise detection of trees could be made. Therefore, this analysis uses a minimum detectable area of trees as 0.2 hectares, which is roughly 45x45m.

Although the Mbale Trees Programme has not been developed to primarily restore dense forests, it is hoped that it has helped to indirectly increase forest cover by providing new, accessible sources of fuel wood to the local population. This should also eliminate the need to cut down trees at the edges of established forests and should enable small woodlots to be used for secondary purposes outside of fuel wood, such as bee keeping, or agroforestry. To note, woodlots *are* also planted under the programme, and these will be picked up by the Sentinel image analysis if established and detectable.

Due to the size of the area in the project (> 1,000 km^2), manually capturing thousands of trees on Sentinel-2 images would be time consuming and prone to significant human error. The ONS-FCDO Hub team has, therefore, developed an automated method of tree detection. This was done using a supervised machine learning algorithm called a Random Forest (Figure 6). A Random Forest is a collection of decision trees. A decision tree is a chain of true or false questions that develop a path to a result. The results from individual decision trees are then merged to make more accurate predictions.

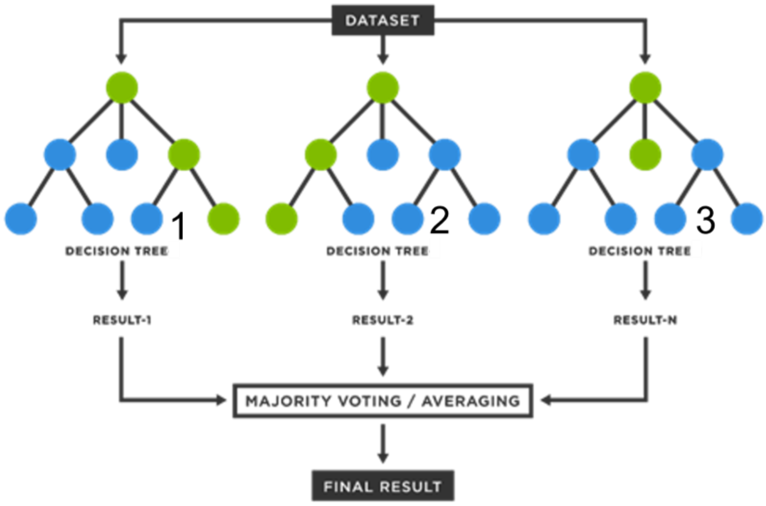


Figure 6: Example of a Random Forest model where decision trees are used to produce the result (modified from Tibco).

The Random Forest algorithm was trained on manually classified areas (polygons of trees or non-trees) in a subsample of image frames from 2016 and 2022. After giving these labels to the Random Forest algorithm, the algorithm was able to classify pixels across a mosaic image using the available bands in Sentinel-2 images, as well as combinations of bands known to be effective in highlighting green vegetation such as the Normalised Difference Vegetation Index (NDVI) which detects photosynthetic vegetation.

Although there are algorithms which can directly predict changes across 2 images, there are slight changes in time of year from the chosen 2 images (January – February) which means that vegetation senescence differs slightly. It was therefore chosen to first detect tree cover in each of the 2 images independently, and then compare these for changes in tree cover which were classified by the Random Forest algorithm (Table 1).

Table 1: Process used to classify forest change from the 2 analysed Sentinel 2 images

Pixel is classified as…	Tree in 2016 image	Non-tree in 2016 image
Tree in 2022 image	*no change*	Tree gain
Non-tree in 2022 image	Tree loss	*no change*

Determining tree cover change per nursery

Once tree cover had been determined in both Sentinel images, and compared to determine tree gain or loss, buffer rings of 0.5km, 1, 2, 3, 4, and 5km were set up around each nursery site. If a tree was detected in 2016 but not 2022 this was seen as tree loss, and vice versa if there were no trees present in 2016, but trees were detected in 2022 this was recorded as tree gain. Figure 7 represents this graphically, showing buffer rings around each METGE nursery, with tree loss and tree gain determined from the Random Forest algorithm across the 2 Sentinel-2 images. These were then tabulated for further analysis.

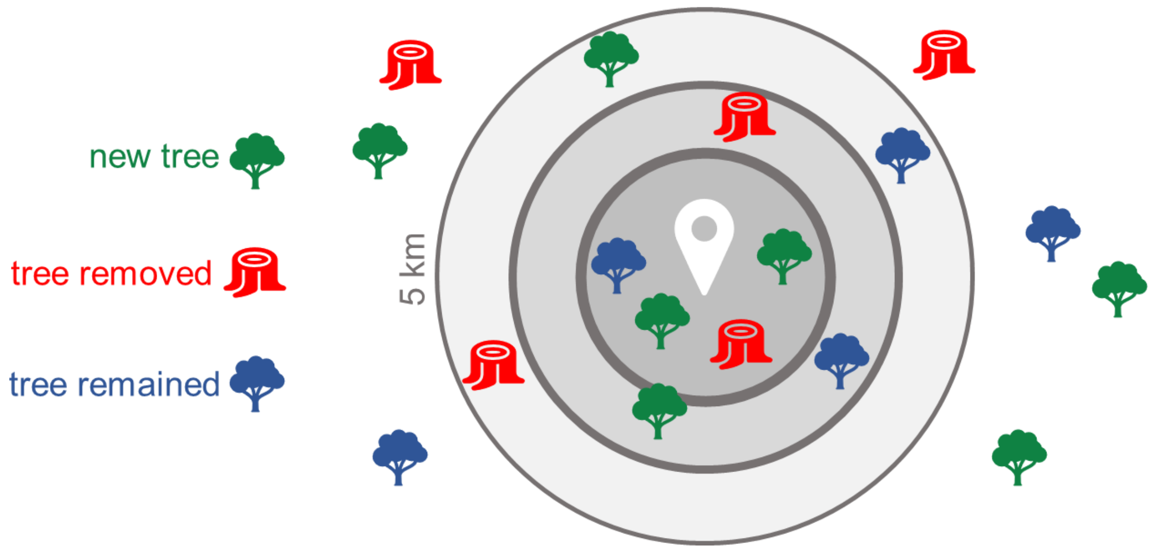


Figure 7: Graphical representation of buffer rings set up around each nursery site. Tree loss and tree gain between 2016-2022 were then calculated per buffered area.

Due to the close proximity of some nurseries to others, many nurseries have overlapping buffer zones. This means in some areas it may be difficult to attribute planting to a single nursery. It is also possible that having multiple nurseries within an area increases knowledge of the programme within the local community, as well as providing more opportunities for acquiring trees, leading to more planting. As such, results are not broken down by individual nurseries but by distances from nurseries (500 m to 5 km). Any tree canopy change beyond 5 km from any nursery is labelled as occurring ‘outside the buffer area’.

Determining tree cover change per District and Sub-County

Since METGE became a Non-Governmental Organisation (NGO) it has a responsibility to report its programme activities to District Officials. Therefore, the areas of tree gain and loss determined from the Random Forest algorithm of analysed Sentinel-2 analysis were also calculated per political area, comparing Districts and sub-county boundaries within the programme area.

Results

The primary method for collecting seedlings from nurseries is by foot or bicycle. This is considered a major limiting factor in how far trees would normally be planted from nurseries. Upon inspection of the Random Forest results, and assuming that most tree gain immediately adjacent to nurseries is due to nursery presence, 5km is seen as the usual tree distribution perimeter from nurseries, since identifiable tree gain drops significantly further away than 5km.

Figure 8 shows an example of the Random Forest algorithm output, whereby tree cover is identified in imagery from 2016 and 2022. Tree cover can be seen as dark green in all images, the top row shows true colour optical imagery from Sentinel-2 and the bottom row shows the vectorised product which is used for further analysis.

Once the vector products were created, the 2 datasets (2016 & 2022) were overlaid with each other thus enabling tree gain, and tree loss to be mapped and calculated, as defined in Table 1.

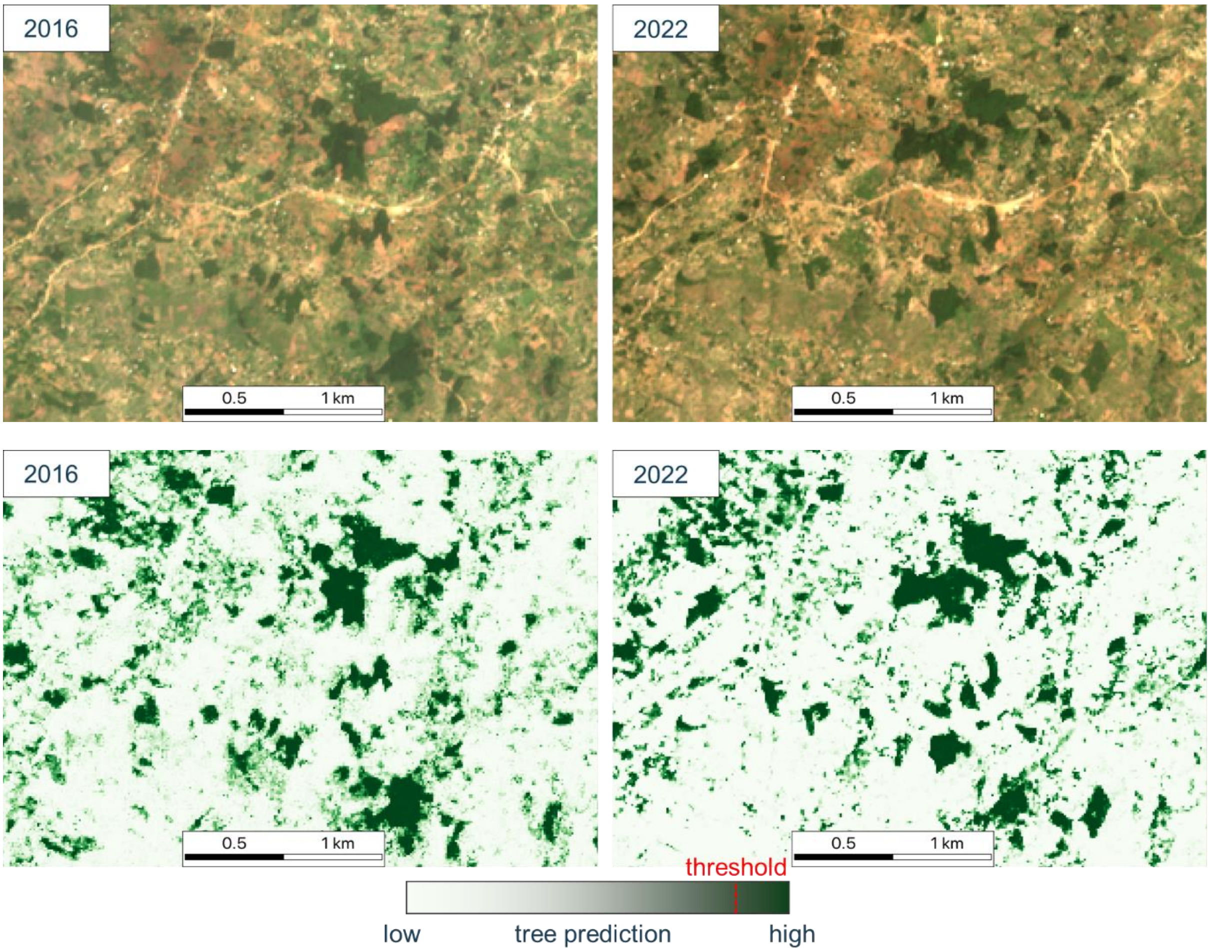


Figure 8: Sentinel-2 imagery from 2016 – 2022 (top) and tree cover (bottom): an output of the Random Forest algorithm, with a set threshold to determine whether the pixel was a tree, or non-tree.

The amount of tree loss, tree gain, and net change determined from comparison of the 2 vector outputs in Figure 8, are shown in Table 2, broken down to buffered distances from the nursery sites.

Table 2: Rates of tree gain, loss, and net change relative to distance from METGE nursery sites.

Buffer zone from nursery	*Tree gain (m² per ha)*	*Tree loss (m² per ha)*	*Net change (m² per ha)*	*Boundary area (km²)*
<0.5 km	*38.58*	*11.46*	*27.12*	*40*
0.5 - 1 km	*41.75*	*15.07*	*26.68*	*112*
1 - 2 km	*55.20*	*20.52*	*34.69*	*374*
2 - 3 km	*49.20*	*14.70*	*34.50*	*449*
3 - 4 km	*47.85*	*9.53*	*38.32*	*408*
4 - 5 km	*57.64*	*10.41*	*47.23*	*343*
outside the buffer	*4.97*	*9.98*	*-5.01*	*3553*

Tree gain

Within the buffered zones, the greatest amount of tree gain is found at 4 to 5 km (57.64 m² per ha) and 1 to 2 km from nurseries (55.2 m² per ha) and the lowest was in the zone closest to the nurseries (less than 0.5 km; 38.58 m² per ha). There is therefore no correlation between the distance from nursery and tree gain (p-value = 0.14, correlation 0.6). However, bearing in mind that the programme started in 2008, areas closest to the nurseries may have already achieved large gains in tree cover, which were not detectable between 2016-2022, meaning that the greatest gains are now visible between 2-5km from nurseries.

Tree gain outside the buffer area is considerably lower than within as shown in Figure 9, with only 4.97 m² per ha. There is, therefore, more tree gain (up to 11 times more) in the areas closer to tree planting nurseries, than in those regions further away (over 5 km).

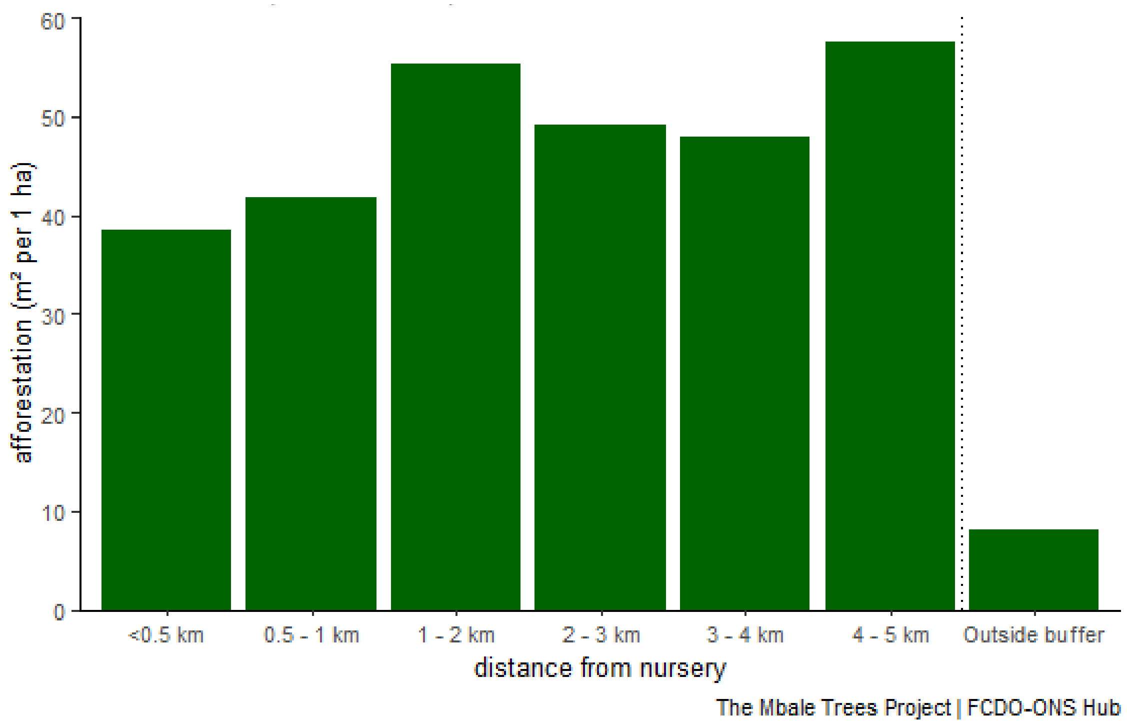


Figure 9: Tree gain identified relative to nursery location - Sentinel image analysis from 2016 – 2022.

Tree loss

With regard to distance from METGE nurseries, there is little variation between buffer distances and tree loss, although there is a slight trend of increasing tree loss 1-2 km from nurseries, that is discontinued from 3 km on-wards. There is no correlation between distance from the nursery and tree loss if the entire 5km radius is considered (p-value = 0.26, correlation 0.49), but there is a strong correlation up to 2 km (p-value = 0.07, correlation 0.99). This lower level of tree loss within 1km of nurseries could be due to increased community engagement from METGE and associated nurseries, though this is not possible to confirm through this report.

Cumulatively, there is more tree loss in the buffered areas (14 m² per 1 ha) compared to the areas outside the 5km buffer (10 m² per 1 ha). This increase in tree loss within 5km of nurseries may be because there are more trees grown and available from the Mbale Tree Programme, which in turn enables communities to cut trees locally in managed agro-forestry systems, as opposed to going further afield. Tree loss between 2016 - 2022 is shown in Figure 10.

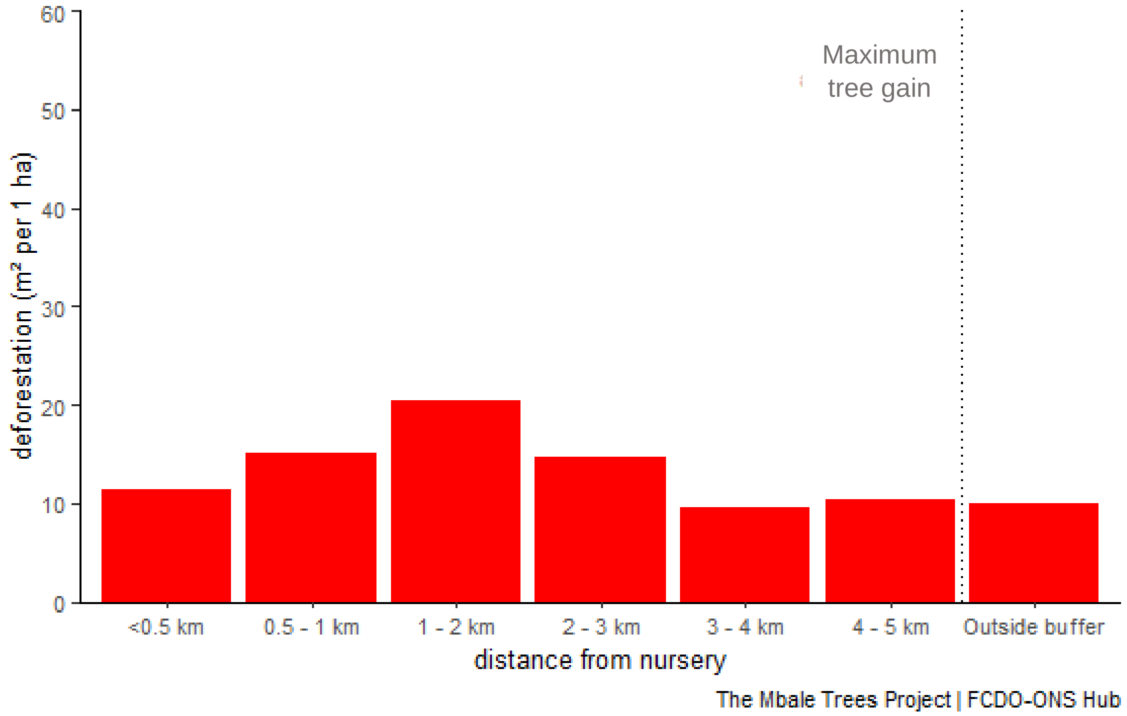


Figure 10: Tree loss identified relative to nursery location - Sentinel image analysis from 2016 – 2022.

The maximum amount of tree loss (21 m² per 1 ha in the 1-2 km buffer) is still significantly smaller than the minimum amount of tree gain (39 m² per 1 ha) within the 5km buffer from nurseries.

Net change

Overall, there is a significant difference between net canopy change depending on distance from METGE nurseries. Within 5km of the nurseries, there is an average net canopy increase of 35m^2 per hectare, which takes into account tree gain, minus tree loss. Outside of the 5km buffer, there is a net loss of tree cover, of 5m^2 per hectare. To clarify, this means that *net* tree gain is on average 7 times larger within 5km of a METGE nursery, whereas in the region overall, trees are lost at a rate of 5m^2 per hectare. There is a strong positive correlation between tree gain and net change (p-value = 4.8 x 10^{-5}, correlation 0.97), suggesting that tree gain is the main driver of change in the region, associated directly to proximity from METGE nurseries.

This report therefore suggests that the Mbale Trees Programme is making a significant positive change with regard to tree cover in the Mbale region. Figure 11 shows this net change in tree cover across the study site analysed using Sentinel-2 imagery.

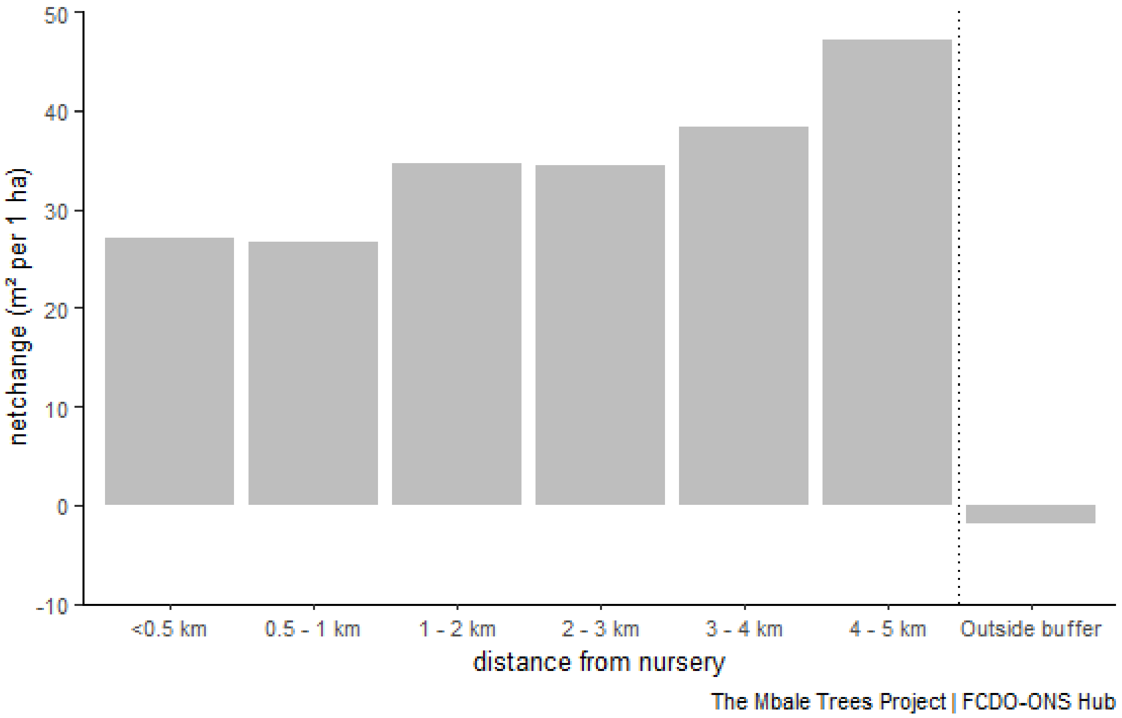


Figure 11: Net tree canopy change relative to nursery location - Sentinel image analysis 2016 - 2022.

Because the 4-5km buffer had the largest positive net change in tree cover, the analysis was broadened to determine how far nursery influence was seen, or if the relationship between tree gain and nursery proximity was not correlative. However, as shown in Figure 12, the largest net tree cover gain is seen at 4-5km from nurseries (57.64 m^2 per ha), and then drops to a net tree canopy loss by 7-8km from nurseries. This adds further evidence to suggest that METGE nurseries are able to influence tree cover up to 5km from their location, but further away impact declines to a point where net tree loss is seen. This is likely due to reduced community engagement from nurseries, as well as difficulty in transporting seedlings, coupled more broadly with population increase, and increasing pressure on land use associated with land fragmentation.

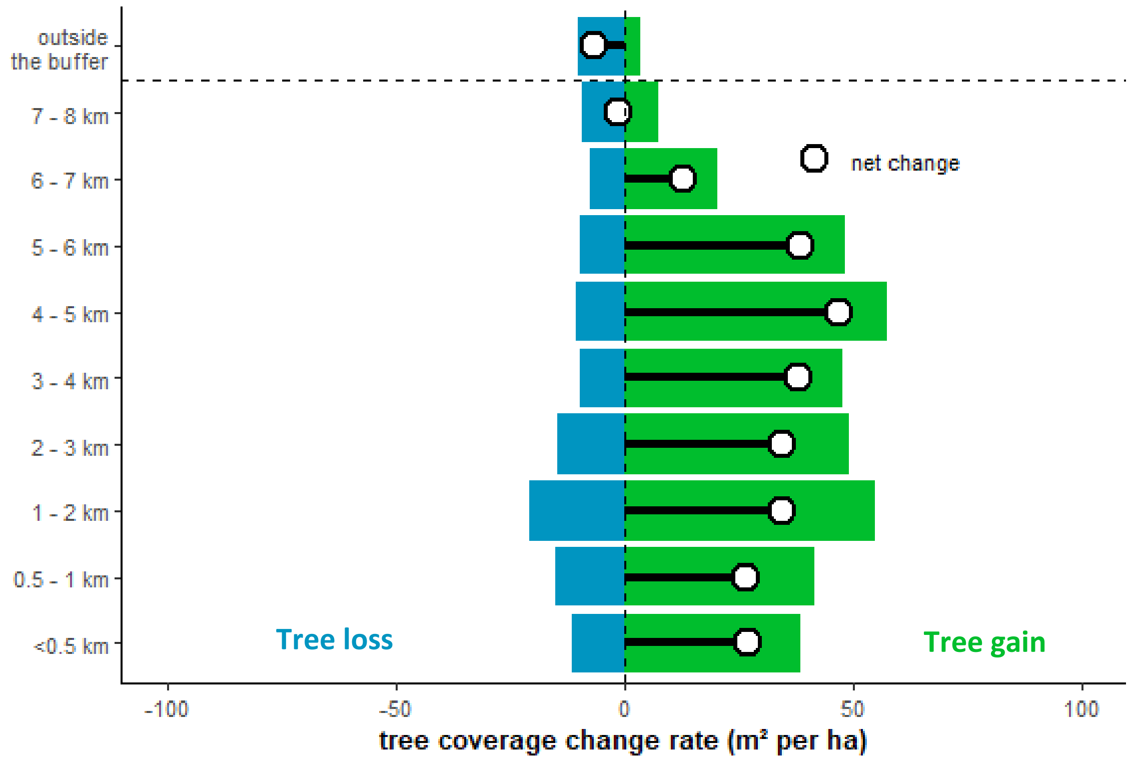


Figure 12: Tree gain (green bars), tree loss (blue bars), and net change in tree canopy (white circles) relative to proximity to METGE nurseries within the Mbale Trees Programme.

As the Mbale Trees Programme began in 2008 and Sentinel-2 images are not available until 2015, it is not possible to use this method to calculate tree cover change since the programme began. There are many factors that could affect tree loss within the buffer zones compared to outside the buffer area. For example, larger amounts of tree loss closer to nurseries (less than 2 km) may correlate with a larger population accessing more local wood fuel, rather than travelling large distances to collect wood fuel. The abundance of trees, an effect of the tree planting programme, may also enable more tree loss thus creating a sustainable fuel wood supply.

Super nurseries

Some METGE nurseries have been designated ‘super’ status, meaning they produce double the number of tree seedlings compared to other nurseries (120,000 per year compared to 60,000 per year). As shown in Figure 13, overall, super nurseries (SNs) have larger tree cover gains than normal nurseries (NN). The greatest difference in tree gain is observed 5 to 6km from nurseries and is 22.53 m² per ha more than normal nurseries. These results would suggest that the doubling of distributed seedlings from super nurseries has a positive impact on the tree cover within 6km of METGE nurseries.

Tree loss rates correlative to super nurseries are virtually unaffected, with the exception of less than 0.5 km and 1 to 2 km, which are lower than when considering all nurseries combined. This is also shown in Figure 13 in the blue bars.

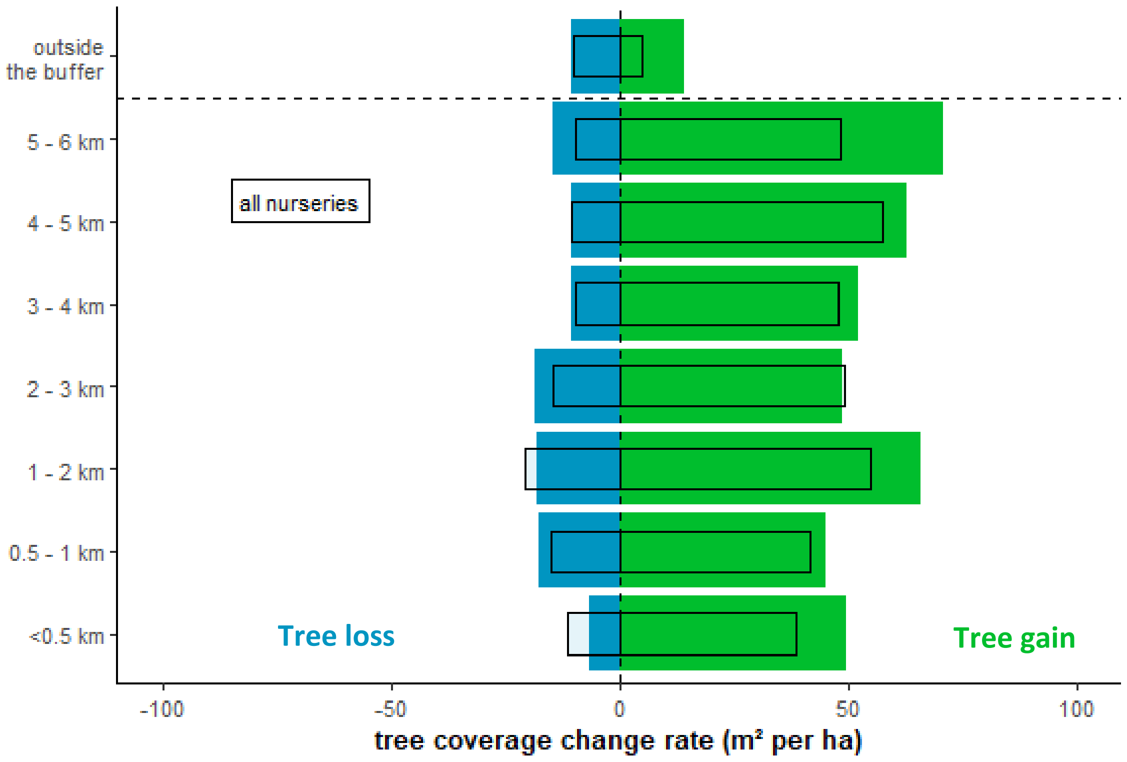


Figure 13: Tree gain (green bars) and tree loss (blue bars) for METGE super nurseries between 2016 - 2022, with figures for all nurseries shown in black outline boxes.

Particularly within 0.5km of METGE nurseries, there is a significant shift in tree cover change at super nursery sites, with +11.06 m² per ha of tree gain, and -4.73 m² per ha of tree loss. Super nursery sites are often designated as they are exemplary in their community engagement, and tree distribution abilities. Considering Table 3 below, as well as Figure 13, it is clear to see that these engaging nurseries are having a larger positive impact in their locality with regard to tree cover.

Table 3: Area of tree gain, loss and net change – comparing super nurseries (SNs to normal nurseries (NN))

Buffer zone-super nursery	*Tree gain from SNs (m² per ha)*	*Tree loss from SNs (m² per ha)*	*Net change from SNs (m² per ha)*	*NN -tree gain (m² per ha)*	*Difference to NN -tree loss (m² per ha)*
<0.5 km	*49.64*	*6.74*	*42.90*	*11.06*	*-4.73*
0.5 - 1 km	*45.05*	*17.72*	*27.33*	*3.30*	*2.65*
1 - 2 km	*66.28*	*18.16*	*48.12*	*11.07*	*-2.36*
2 - 3 km	*48.71*	*18.29*	*29.88*	*-0.49*	*3.58*
3 - 4 km	*52.26*	*10.50*	*41.76*	*4.41*	*0.97*
4 - 5 km	*62.90*	*10.59*	*52.31*	*5.26*	*0.17*
5 - 6 km	*70.93*	*14.42*	*56.51*	*22.53*	*4.62*
outside buffer	*14.48*	*10.67*	*3.81*	*9.51*	*0.69*

Districts

The Mbale Trees Programme has tree nurseries in seven Districts of eastern Uganda (Bududa, Bukedea, Bulambuli, Manafwa, Mbale, Namisindwa, and Sironko). The volume of tree gain and tree loss from 2016-2022 per District is shown in Table 4 and represented graphically in Figure 14. There is also a full breakdown per area in Appendix 1.

Table 4: Area of tree gain, loss, and net change per District - 2016 – 2022, from Sentnel-2 analysis.

District	*Tree gain (m² per ha)*	*Tree loss (m² per ha)*	*Net change (m² per ha)*
Bududa	*82.63*	*26.11*	*56.52*
Bukedea	*2.27*	*0.95*	*1.32*
Bulambuli	*19.88*	*6.60*	*13.28*
Manafwa	*70.66*	*11.59*	*59.07*
Mbale	*51.75*	*14.12*	*37.62*
Namisindwa	*20.76*	*8.75*	*12.01*
Sironko	*105.90*	*22.78*	*83.12*

All of the 7 Districts within the programme area have a net tree gain from 2016 - 2022, with Sironko having the largest tree gains and losses, and Bukedea the smallest. The grey dots in Figure 14 show the largest outlying tree gain or loss and represent sub-counties within each District. The other resultant sub-counties are represented in the green and blue bars. Tree loss was overall much less abundant than tree gain, and there is a positive correlation between tree gain and net change, but not tree loss and net change. This suggests that the canopy cover change in the analysed Districts is largely due to new trees being present, as opposed to tree loss.

These results are also shown geographically in Figure 15, broken down by District and sub-county. Sub-counties on the outskirts of the region are more likely to have a negative net change as shown in Figure 15 (C). These sub-counties are further away from major towns, as well as tree planting nurseries, and indicate areas of greater tree loss than tree gain.

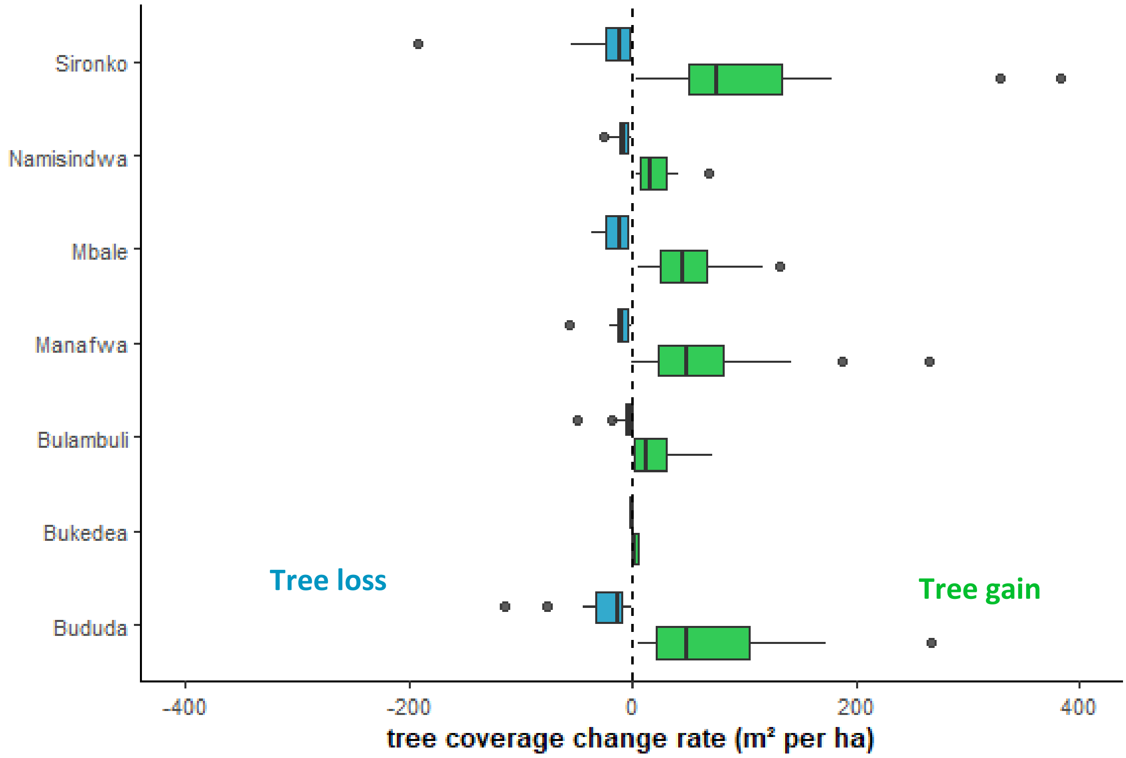


Figure 14: Tree gain (green) and tree loss (blue) per District, determined from Sentinel-2 analysis 2016 – 2022. Grey dots represent outlying sub-counties with exceptional tree gain, or loss.

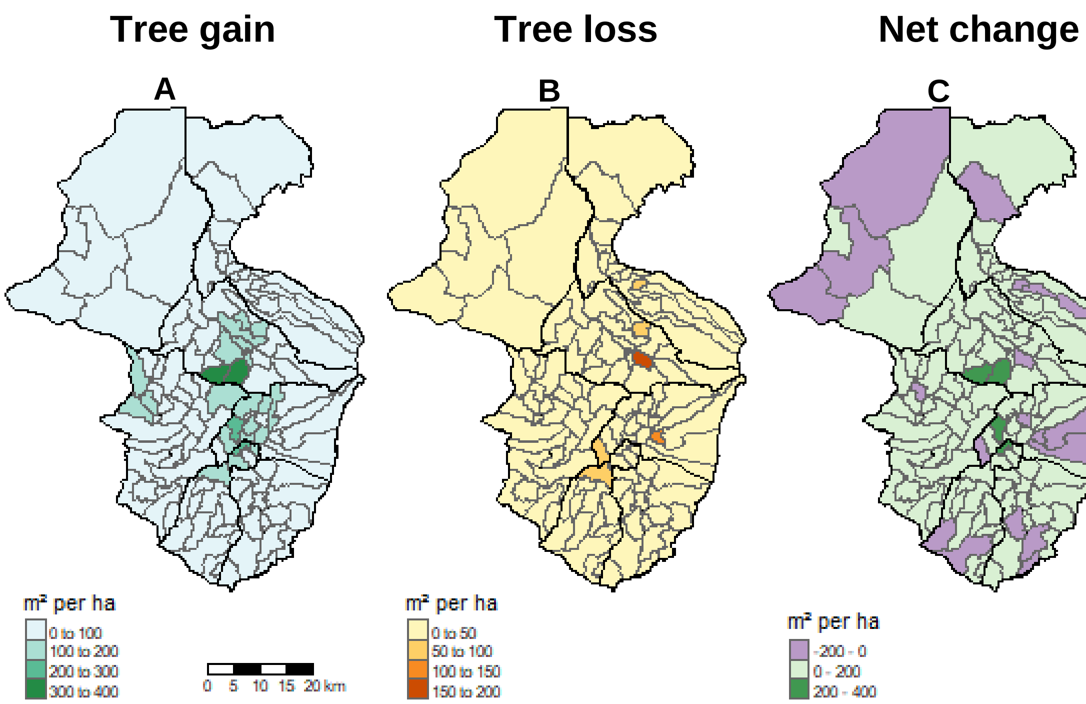


Figure 15: Tree gain (A), tree loss (B), and net canopy change (C) across the programme area 2016 – 2022, determined by Sentinel-2 change detection, shown by District (thick black lines) & sub-county (thin black lines).

The mean net change per District is represented in Figure 16, whereby there is a clear pattern of increased canopy cover as a net change across all Districts. Bududa, Manafwa, and Sironko have the largest net positive change, with Bukedea showing minimal net change, though still more tree gain than loss from 2016 – 2022.

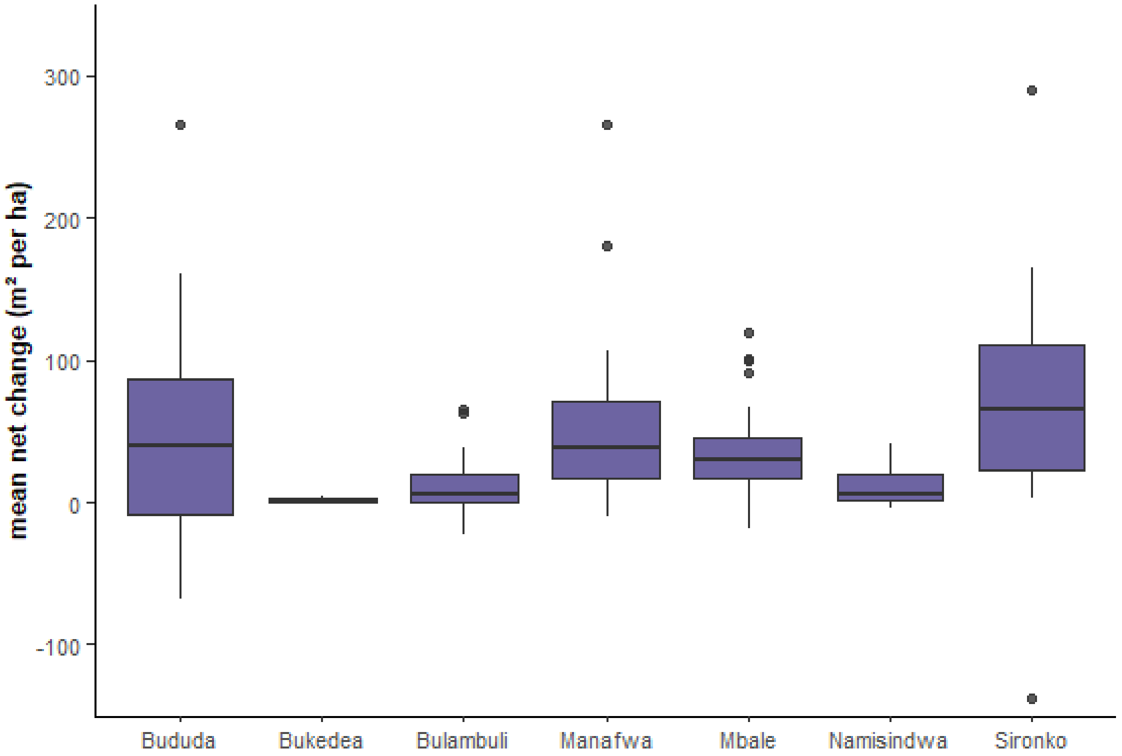


Figure 16: Mean net canopy change detected using Sentinel-2 image analysis for each District.

It is not possible to say whether this net canopy gain is a direct result of the Mbale Trees Programme, and the work of METGE and its tree nurseries. However, coupled with the results looking specifically at canopy gain correlative to tree nurseries, this would suggest that METGE is having a positive overall impact on the Districts it is working in with regard to tree canopy cover.

The limitation to making comparisons between Districts and their sub-counties, is the variation in population, which also follows differences in geography and land use. Population data at a sub-county level for eastern Uganda are not currently available, however, the Uganda Bureau of Statistics 2020 census breaks down population at a District level. Figure 17 shows the rates of tree gain, tree loss, and net canopy change per person for each District. Mbale has the highest population (488,960), with its population double that of other Districts (next largest is Sironko at 242,421). Mbale, however, does not have the highest tree gain or loss per person. The greatest amount of tree gain per person is in Sironko (14.8 m^2/person) compared to the next largest at 8 m^2/person (Manafwa and Bududa). These also correlate with the highest levels of tree loss per person - with a direct correlation between tree gain and tree loss per person. This is closely linked to the population of the Districts, and it is unsurprising that the more populous Districts would see more tree loss.

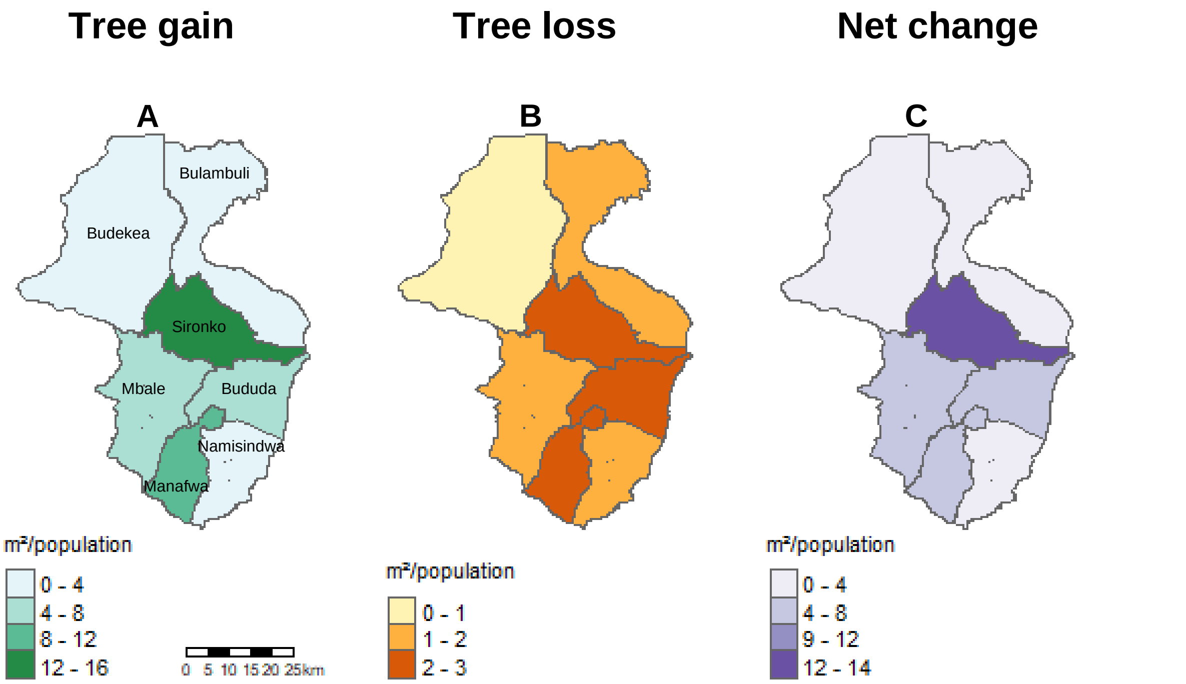


Figure 17: Tree gain (A), tree loss (B), and net canopy change (C) per capita across the Mbale Trees Programme area.

Limitations and caveats

This analysis was designed to understand the impact of the Mbale Trees Programme on tree coverage in eastern Uganda. The focus was on doing this with an accessible, reproducible, open-source method. The first step was to quantify the change in tree cover in the area. If there had been no change, this would negate the need for further exploration. Having identified an increase in tree cover in the areas surrounding METGE tree planting nurseries, the next steps were to try and quantify how much of this tree gain was a direct result of the Mbale Trees Programme. There are limitations to the approach used here however, that prevent us from directly attributing tree gain to the programme, though correlation is such that it is very likely that the METGE tree nurseries have enabled increased tree cover in the region.

Comparing to a baseline

A major limitation is that the programme predates the launch of Sentinel-2, which means that we cannot use Sentinel-2 to find a baseline for tree coverage before 2010. This means that we do not know how much tree growth or loss typically occurred in the areas of interest before the programme began.

In this analysis, we compare areas within and outside buffered zones. Differences in demographics and geography, however, are also likely to impact results that cannot be easily accounted for with the available data. A potential solution would be to find another region in Uganda with similar demographics and geography that could be used as a baseline comparison.

Finding a suitable area to use as a baseline comparison, however, is not straight-forward. Deforestation in Uganda has been a widespread, national problem for some time, with a loss of -26.3% of forest cover estimated between 1990 and 2005 (5 million ha; Uganda National Environment Management Authority). The Mbale Trees Programme has focused its attention on eastern Uganda whereby there is a combination of high deforestation rates and hilly terrain leading to deadly landslides. In northern Uganda, refugees fleeing conflict in South Sudan and Democratic Republic of the Congo have been settled in the area, which is thought to be driving deforestation through the use of timber for construction and fuel. This would add socio-economic factors to the analysis whose affects would be very difficult to quantify. In the south, increasing urbanisation and expanding farmland are driving deforestation, which again adds an extra socio-economic dimension that would have to be accounted for.

Increasing spatial resolution

The Mbale Trees Programme aims to provide trees that can be planted on community land and smallholdings. The supply of tree seedlings means that they become a “renewable” resource, preventing the need to cut down trees on the edge of more established forests. The resolution of Sentinel-2 images (10 m / pixel) means the work was unable to detect smaller, individual tree canopies. Instead, measurements focussed on growth and loss of more established forests, a secondary impact of the programme. One solution to look in more detail at MTEGE’s influence on tree cover could be to use higher-resolution satellite images. The storage and processing requirements of these commercial images, however, mean that the process is no longer easily reproducible, and a more focused approach to areas would be required. However, the results from Sentinel-2 images combined with local knowledge of the program, provided the data needed to conclude that the programme is likely influencing the region’s tree cover directly.

Conclusions

The results of this analysis have shown that between 2016 and 2022 there was a significant positive net change in tree growth in the entire programme area. This tree canopy gain is concentrated within 5 km of METGE tree planting nurseries (+35 m^2 per ha, compared to -5 m^2 per ha tree loss >5km). Tree loss occurs at its highest rate within 2 km of the tree planting nurseries. However, tree gain occurs at an even higher rate so net change remains positive.

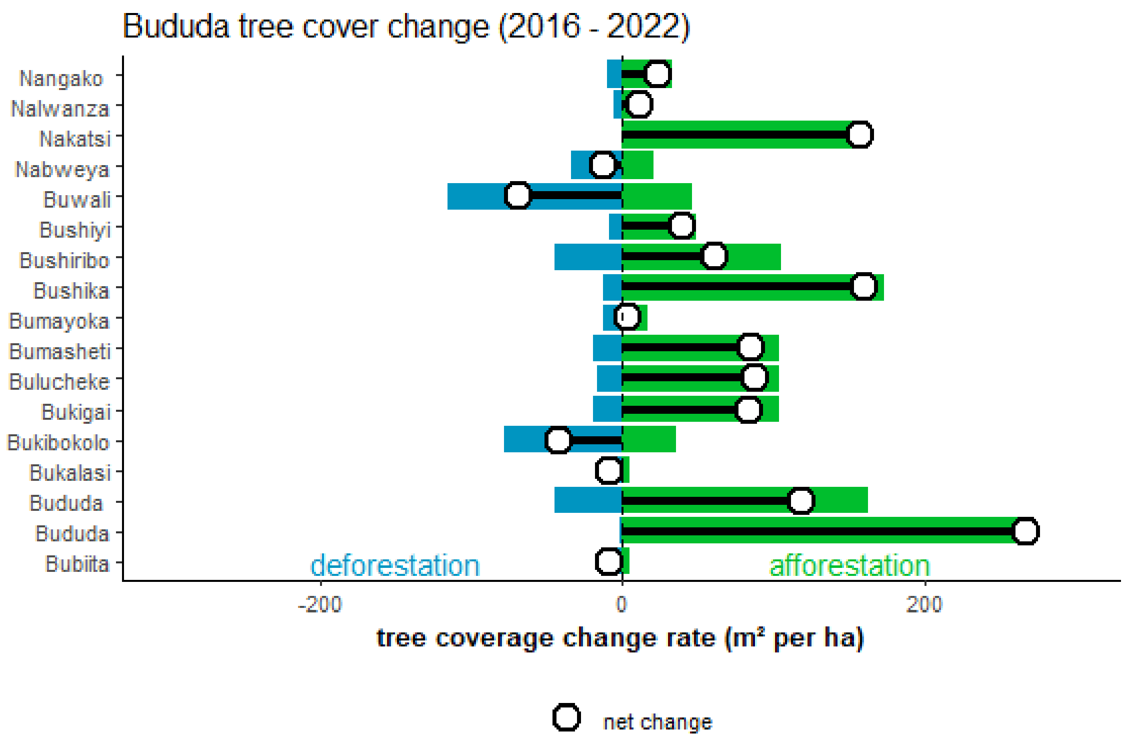
These findings are consistent with assumptions from the programme that many trees planted close to the nursery are being used for fuel wood. This report concludes that the programme is likely reducing the need for logging of mature, established trees at the edges of forests further away, as the programme trees provide a sustainable fuel wood source, as well as providing many other benefits to the communities, as well as the local and global environment. If the current rates are maintained, planting of trees would continue to offset deforestation, near the nursery sites. Outside of the buffer zones, at distances greater than 5 km from the nursery locations, tree loss is still exceeding tree gains (a negative net change).

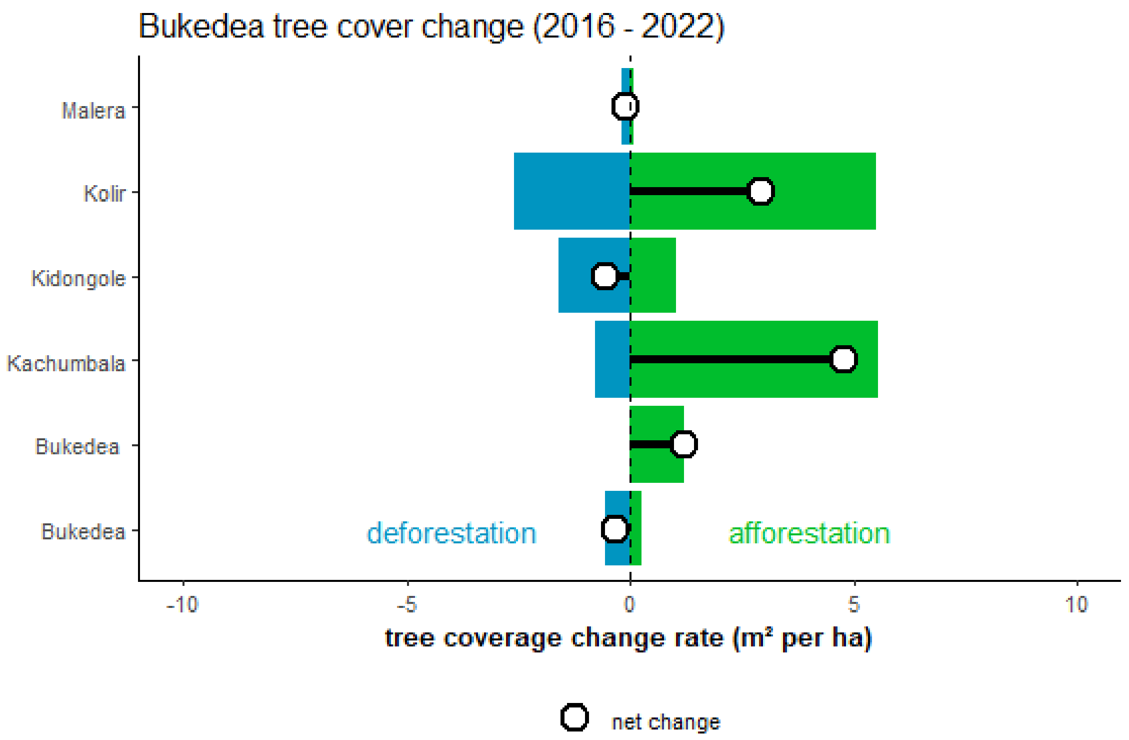
At the District level, negative net changes occur in the sub-counties at the edges of the region. These sub-counties are the furthest away from the nurseries. There is a direct positive correlation between tree gain and net change across sub-counties, and the greatest net change is observed in sub-counties with access to multiple nurseries. In general, there is very little variation in the amount of tree loss across sub-counties (with the exception of some outliers) compared to the variation in tree gain. Cooperation with local partners is needed to understand why some sub-counties have such high tree loss rates. It is worth noting that the highest tree loss occurs at the boundary of the national park and could be related to specific activities of the national park itself. Those sub-counties with outlier tree loss rates also have negative net changes. While tree gain is the greatest factor in tree cover change, it does not offset high tree loss in some areas. Overall though, each of the 7 Districts sees positive net change regarding tree cover. Considering that Uganda has a national deforestation rate of 4% (UBOS, 2022), the net tree gain in all Districts that METGE is working within, suggests that the programme is having a large positive impact, with up to 7 times more trees within 5km of METGE nurseries.

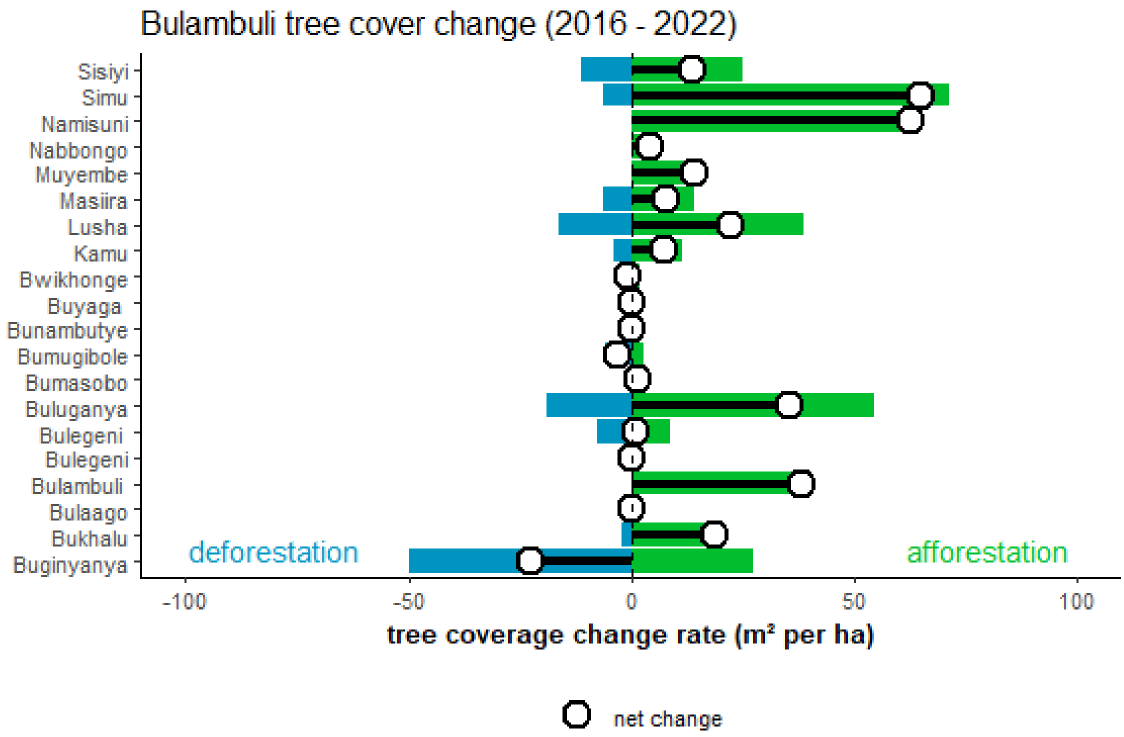
It is worth noting that the greatest amounts of tree gain and tree loss are linked to population of the Districts. This is not an unsurprising conclusion because the more people, the greater the need for wood fuel. Without a baseline, however, it is difficult to say confidently that tree gain should also increase with the population. However, from this report, it is known that the Districts with the largest population also have the largest number of tree planting nurseries, and this is where the greatest amount of consistent tree gain is being observed.

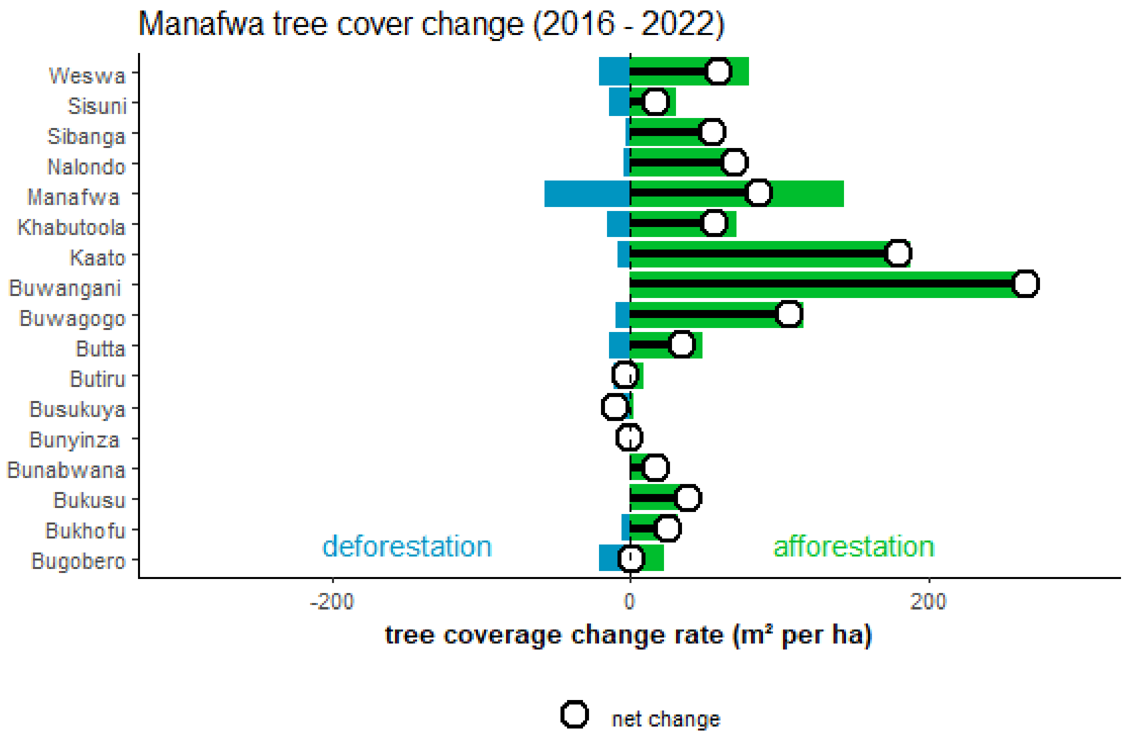
Considering the national trend of deforestation, once again, to see tree gain in the 7 Districts that the programme operates in adds weight to the idea that there is more canopy cover 2016 – 2022, directly as an influence of the tree Mbale Trees Programme.

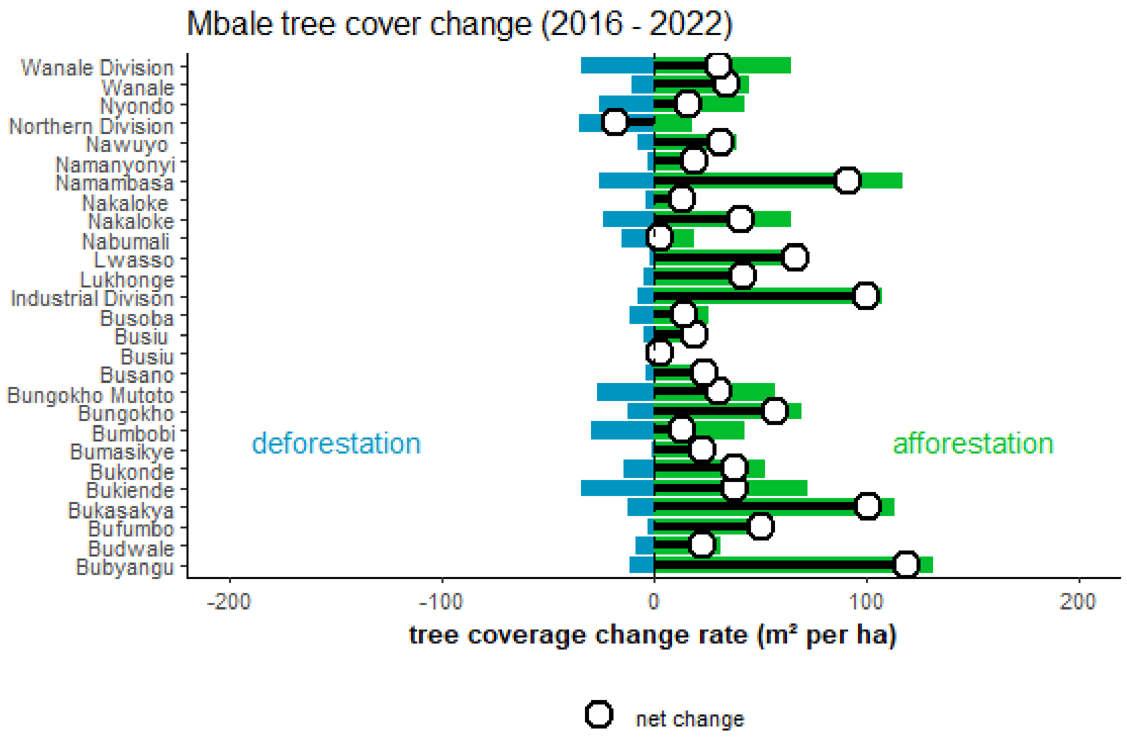
Appendix 1 – Tree gain, loss, and net change per District & Sub-County

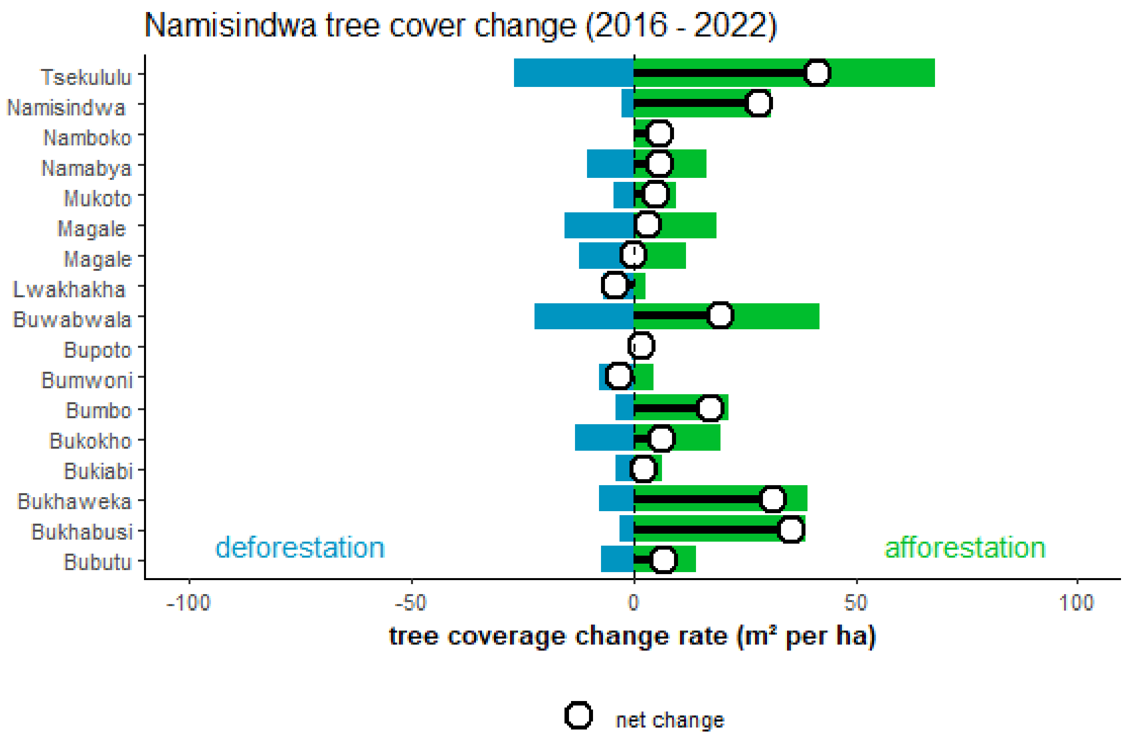


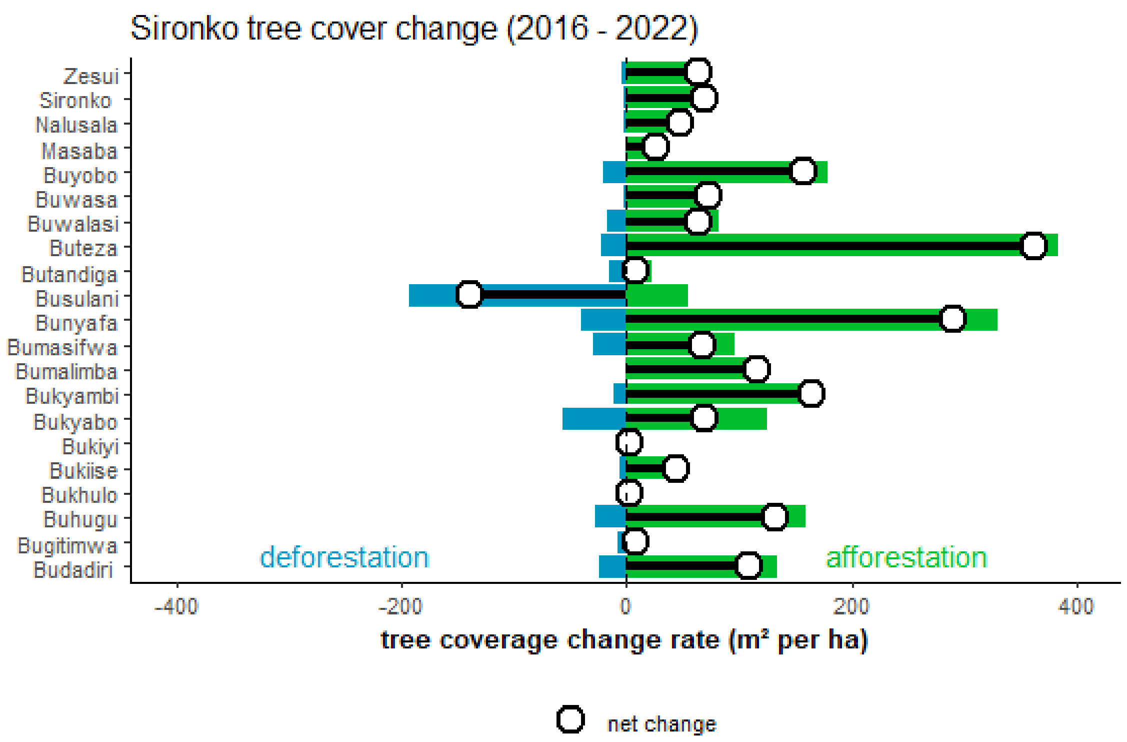



Bulambuli tree cover change (2016 - 2022)
Sisiyi
Simu
Namisuni
Nabbongo
Muyembe
Masiira
Lusha
Kamu
Bwikhonge
Buyaga
Bunambutye
Bumugibole
Bumasobo
Buluganya
Bulegeni
Bulegeni
Bulambuli
Bulaago
Bukhalu
Buginyanya
deforestation
afforestation
-100
-50
0
50
100
tree coverage change rate (m² per ha)
net change


Manafwa tree cover change (2016 - 2022)
Weswa
Sisuni
Sibanga
Nalondo
Manafwa
Khabutoola
Kaato
Buwangani
Buwagogo
Butta
Butiru
Busukuya
Bunyinza
Bunabwana
Bukusu
Bukhofu
Bugobero
deforestation
afforestation
-200
0
200
tree coverage change rate (m² per ha)
net change


Mbale tree cover change (2016 - 2022)
Wanale Division
Wanale
Nyondo
Northern Division
Nawuyo
Namanyonyi
Namambasa
Nakaloke
Nakaloke
Nabumali
Lwasso
Lukhonge
Industrial Divison
Busoba
Busiu
Busiu
Busano
Bungokho Mutoto
Bungokho
Bumbobi
Bumasikye
Bukonde
Bukiende
Bukasakya
Bufumbo
Budwale
Bubyangu
deforestation
afforestation
-200
-100
0
100
200
tree coverage change rate (m² per ha)
net change


Namisindwa tree cover change (2016 - 2022)
Tsekululu
Namisindwa
Namboko
Namabya
Mukoto
Magale
Magale
Lwakhakha
Buwabwala
Bupoto
Bumwoni
Bumbo
Bukokho
Bukiabi
Bukhaweka
Bukhabusi
Bubutu
deforestation
afforestation
-100
-50
0
50
100
tree coverage change rate (m² per ha)
net change



District	Tree gain (m² per ha)	Tree loss (m² per ha)	Net change (m² per ha)
Bududa	*1404.73*	*443.85*	*960.88*
Bukedea	*13.63*	*5.73*	*7.90*
Bulambuli	*397.55*	*132.00*	*265.55*
Manafwa	*1201.24*	*197.09*	*1004.15*
Mbale	*1397.14*	*381.37*	*1015.78*
Namisindwa	*352.93*	*148.72*	*204.22*
Sironko	*2223.99*	*478.47*	*1745.52*

District	subcounty	Tree gain (m² per ha)	Tree loss (m² per ha)	Net change (m² per ha)
Bududa	*Bubiita*	*4.43*	*12.30*	*-7.87*
Bududa	*Bududa*	*268.39*	*1.83*	*266.55*
Bududa	*Bududa*	*163.19*	*44.26*	*118.93*
Bududa	*Bukalasi*	*5.30*	*13.16*	*-7.86*
Bududa	*Bukibokolo*	*35.87*	*77.30*	*-41.43*

Bududa	*Bukigai*	*103.20*	*19.18*	*84.02*
Bududa	*Bulucheke*	*103.31*	*15.91*	*87.40*
Bududa	*Bumasheti*	*103.57*	*18.79*	*84.78*
Bududa	*Bumayoka*	*16.39*	*12.29*	*4.10*
Bududa	*Bushika*	*173.09*	*12.55*	*160.54*
Bududa	*Bushiribo*	*104.92*	*44.26*	*60.66*
Bududa	*Bushiyi*	*48.65*	*8.73*	*39.92*
Bududa	*Buwali*	*46.05*	*114.73*	*-68.68*
Bududa	*Nabweya*	*21.18*	*33.41*	*-12.23*
Bududa	*Nakatsi*	*157.20*	*0.00*	*157.20*
Bududa	*Nalwanza*	*16.72*	*5.23*	*11.50*
Bududa	*Nangako*	*33.27*	*9.93*	*23.34*
Bukedea	*Bukedea*	*0.24*	*0.58*	*-0.34*
Bukedea	*Bukedea*	*1.20*	*0.00*	*1.20*
Bukedea	*Kachumbala*	*5.55*	*0.77*	*4.78*
Bukedea	*Kidongole*	*1.04*	*1.59*	*-0.55*
Bukedea	*Kolir*	*5.51*	*2.58*	*2.93*
Bukedea	*Malera*	*0.10*	*0.20*	*-0.11*
Bulambuli	*Buginyanya*	*27.38*	*50.01*	*-22.63*
Bulambuli	*Bukhalu*	*20.64*	*2.09*	*18.55*
Bulambuli	*Bulaago*	*0.00*	*0.00*	*0.00*
Bulambuli	*Bulambuli*	*38.25*	*0.00*	*38.25*
Bulambuli	*Bulegeni*	*0.00*	*0.00*	*0.00*
Bulambuli	*Bulegeni*	*8.63*	*7.79*	*0.84*
Bulambuli	*Buluganya*	*54.45*	*19.16*	*35.29*
Bulambuli	*Bumasobo*	*2.05*	*0.52*	*1.54*
Bulambuli	*Bumugibole*	*2.61*	*5.67*	*-3.06*
Bulambuli	*Bunambutye*	*0.45*	*0.31*	*0.14*
Bulambuli	*Buyaga*	*0.00*	*0.00*	*0.00*
Bulambuli	*Bwikhonge*	*1.93*	*2.71*	*-0.78*

Bulambuli	*Kamu*	*11.27*	*3.93*	*7.35*
Bulambuli	*Lusha*	*38.52*	*16.19*	*22.33*
Bulambuli	*Masiira*	*14.14*	*6.16*	*7.98*
Bulambuli	*Muyembe*	*13.99*	*0.00*	*13.99*
Bulambuli	*Nabbongo*	*4.02*	*0.00*	*4.02*
Bulambuli	*Namisuni*	*62.69*	*0.00*	*62.69*
Bulambuli	*Simu*	*71.53*	*6.39*	*65.14*
Bulambuli	*Sisiyi*	*24.99*	*11.08*	*13.92*
Manafwa	*Bugobero*	*22.61*	*21.13*	*1.48*
Manafwa	*Bukhofu*	*31.55*	*6.11*	*25.44*
Manafwa	*Bukusu*	*39.10*	*0.00*	*39.10*
Manafwa	*Bunabwana*	*17.60*	*0.25*	*17.34*
Manafwa	*Bunyinza*	*0.11*	*0.00*	*0.11*
Manafwa	*Busukuya*	*2.89*	*12.71*	*-9.82*
Manafwa	*Butiru*	*8.89*	*11.40*	*-2.50*
Manafwa	*Butta*	*48.54*	*13.53*	*35.02*
Manafwa	*Buwagogo*	*116.37*	*9.50*	*106.87*
Manafwa	*Buwangani*	*265.33*	*0.00*	*265.33*
Manafwa	*Kaato*	*188.57*	*8.57*	*180.00*
Manafwa	*Khabutoola*	*72.23*	*15.10*	*57.14*
Manafwa	*Manafwa*	*143.27*	*57.15*	*86.12*
Manafwa	*Nalondo*	*74.60*	*4.09*	*70.51*
Manafwa	*Sibanga*	*59.10*	*3.28*	*55.82*
Manafwa	*Sisuni*	*30.26*	*13.62*	*16.65*
Manafwa	*Weswa*	*80.22*	*20.65*	*59.57*
Mbale	*Bubyangu*	*131.13*	*12.00*	*119.13*
Mbale	*Budwale*	*31.35*	*8.57*	*22.78*
Mbale	*Bufumbo*	*52.66*	*2.69*	*49.98*
Mbale	*Bukasakya*	*112.94*	*12.38*	*100.56*
Mbale	*Bukiende*	*72.33*	*34.25*	*38.08*

Mbale	*Bukonde*	*51.95*	*14.09*	*37.86*
Mbale	*Bumasikye*	*24.64*	*1.67*	*22.97*
Mbale	*Bumbobi*	*42.62*	*29.46*	*13.16*
Mbale	*Bungokho*	*69.26*	*12.31*	*56.96*
Mbale	*Bungokho Mutoto*	*56.53*	*26.75*	*29.78*
Mbale	*Busano*	*27.73*	*4.32*	*23.41*
Mbale	*Busiu*	*4.76*	*2.43*	*2.34*
Mbale	*Busiu*	*23.36*	*4.86*	*18.50*
Mbale	*Busoba*	*25.38*	*11.49*	*13.89*
Mbale	*Industrial Divison*	*107.34*	*7.67*	*99.67*
Mbale	*Lukhonge*	*47.17*	*5.43*	*41.74*
Mbale	*Lwasso*	*69.05*	*2.38*	*66.67*
Mbale	*Nabumali*	*18.44*	*15.76*	*2.68*
Mbale	*Nakaloke*	*64.63*	*24.39*	*40.24*
Mbale	*Nakaloke*	*16.81*	*4.06*	*12.74*
Mbale	*Namambasa*	*116.94*	*25.54*	*91.40*
Mbale	*Namanyonyi*	*22.20*	*3.35*	*18.85*
Mbale	*Nawuyo*	*39.14*	*8.30*	*30.83*
Mbale	*Northern Division*	*17.51*	*35.87*	*-18.36*
Mbale	*Nyondo*	*42.36*	*26.43*	*15.92*
Mbale	*Wanale*	*44.72*	*10.67*	*34.05*
Mbale	*Wanale Division*	*64.20*	*34.24*	*29.96*
Namisindwa	*Bubutu*	*14.08*	*7.12*	*6.96*
Namisindwa	*Bukhabusi*	*38.85*	*3.16*	*35.69*
Namisindwa	*Bukhaweka*	*39.08*	*7.72*	*31.35*
Namisindwa	*Bukiabi*	*6.30*	*4.15*	*2.15*
Namisindwa	*Bukokho*	*19.87*	*13.29*	*6.59*
Namisindwa	*Bumbo*	*21.39*	*3.86*	*17.53*
Namisindwa	*Bumwoni*	*4.48*	*7.43*	*-2.95*
Namisindwa	*Bupoto*	*2.26*	*0.52*	*1.74*

Namisindwa	*Buwabwala*	*41.85*	*22.23*	*19.62*
Namisindwa	*Lwakhakha*	*2.90*	*6.93*	*-4.03*
Namisindwa	*Magale*	*11.97*	*12.07*	*-0.09*
Namisindwa	*Magale*	*18.64*	*15.57*	*3.06*
Namisindwa	*Mukoto*	*9.82*	*4.65*	*5.16*
Namisindwa	*Namabya*	*16.45*	*10.56*	*5.88*
Namisindwa	*Namboko*	*5.94*	*0.00*	*5.94*
Namisindwa	*Namisindwa*	*30.94*	*2.80*	*28.14*
Namisindwa	*Tsekululu*	*68.13*	*26.66*	*41.47*
Sironko	*Budadiri*	*133.47*	*24.69*	*108.78*
Sironko	*Bugitimwa*	*15.78*	*6.91*	*8.87*
Sironko	*Buhugu*	*158.92*	*27.19*	*131.73*
Sironko	*Bukhulo*	*2.45*	*0.00*	*2.45*
Sironko	*Bukiise*	*50.40*	*5.76*	*44.65*
Sironko	*Bukiyi*	*5.41*	*3.11*	*2.30*
Sironko	*Bukyabo*	*124.83*	*55.49*	*69.35*
Sironko	*Bukyambi*	*175.80*	*10.54*	*165.26*
Sironko	*Bumalimba*	*116.85*	*0.00*	*116.85*
Sironko	*Bumasifwa*	*96.06*	*29.00*	*67.06*
Sironko	*Bunyafa*	*330.02*	*39.65*	*290.37*
Sironko	*Busulani*	*54.92*	*192.96*	*-138.04*
Sironko	*Butandiga*	*22.40*	*14.16*	*8.24*
Sironko	*Buteza*	*384.12*	*22.34*	*361.79*
Sironko	*Buwalasi*	*81.99*	*17.03*	*64.96*
Sironko	*Buwasa*	*75.96*	*2.30*	*73.66*
Sironko	*Buyobo*	*178.80*	*20.34*	*158.46*
Sironko	*Masaba*	*27.25*	*0.00*	*27.25*
Sironko	*Nalusala*	*49.77*	*1.09*	*48.67*
Sironko	*Sironko*	*71.20*	*1.72*	*69.49*
Sironko	*Zesui*	*67.59*	*4.20*	*63.38*