**IGC 2021**

**Workflow and guidelines for estimating project contributions to the Trillion Tree Initiative and to global carbon sequestration.**

Three issues are highlighted by the work below. First, that the differences in carbon storage capacity between large and small trees creates a huge challenge for any scenario that incorporates the harvesting of trees. To achieve global carbon goals will demand dramatically more tree conservation. Second, that the numbers of newly planted trees required, and thus projects, are staggering if local projects are scaled in the attempt to address national problems. Third, that even in this simple set of scenarios, if plans don't account for the space needed for shelter, commerce, food, water and energy production, and population growth they negate the possibility of tree-growing being able to address global GHG production. The best of the scenarios below achieves 3.46T/person of sequestration, below the global average GHG production of 4.8T. Within the global number there is huge variation, from 38T/person for Qatar to 0.1T/person for Uganda. The people in the 0.1T/person countries are striving to reach the quality of life of those of us that use 16T/person. If carbon sequestration does not out-perform GHG production, then we are doomed to continued global warming.

Five steps are required to calculate the effects of geodesign scenarios on tree numbers and carbon storage. These calculations will need to be conducted individually for each major land-use system in the design (e.g., Agriculture, Forest, Mixed-use) and the results summed for reporting in the IGC format:

1. **Develop baseline measures**

   Observed changes in tree numbers and carbon stocks under Early and Late adopter scenarios must be compared against the Non-adopter 'business as usual' scenario that would have happened in the absence of project activities.

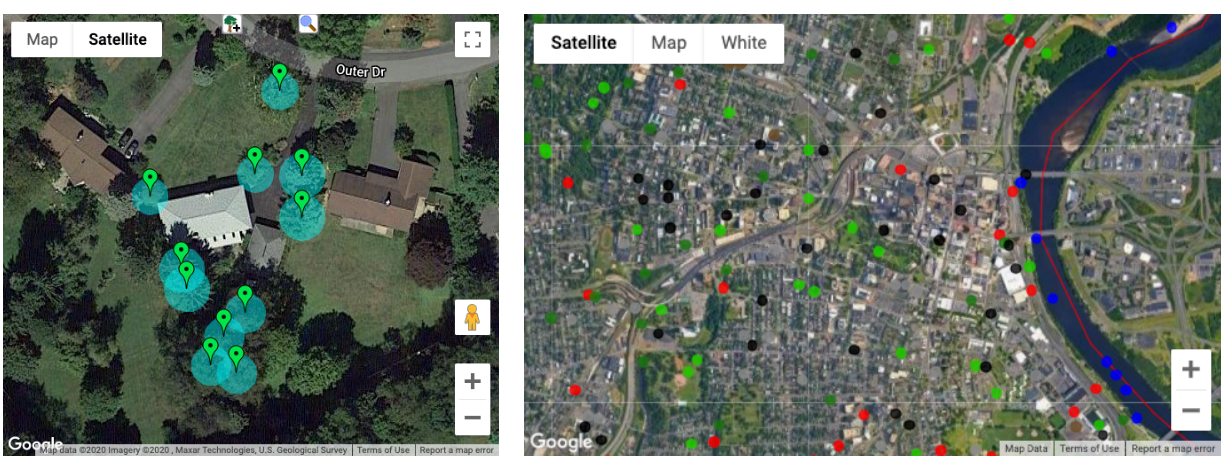



Figure 1. (a) Individual trees located using iTree Design (b) Land cover types sampled using iTree Canopy. Both tools yield carbon storage estimates.

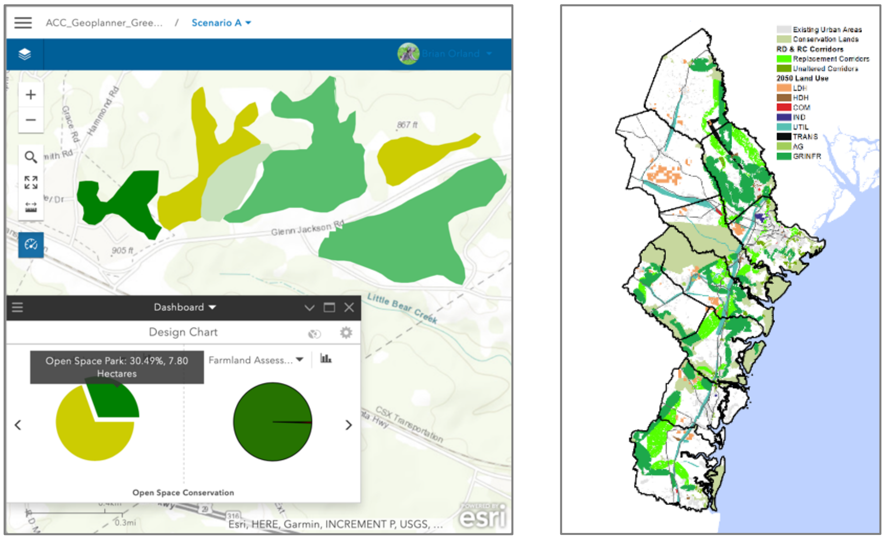



Figure 2. Areas of existing and projected land use change delineated and measured using GIS-based tools: (a) ESRI GeoPlanner, (b) Geodesignhub.

The starting or baseline scenario is compiled by estimating the carbon storage of all reference regions or projects in the study area. For example, tree numbers in forested or cropland areas can be calculated by reference to the resources at https://www.igc-geodesign.org/estimate-trees-and-carbon, carbon storage can be estimated by reference to the IPCC guidance (https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html). Tree numbers in developed areas can be counted or estimated from design documents or aerial imagery, associated carbon storage by reference to the estimation tools referenced at https://www.igc-geodesign.org/estimate-trees-and-carbon (Figures 1 and 2).

## 2. Determine change in numbers of trees for IGC scenarios and time-steps

Changes in tree numbers are associated with Land Use/Land Cover changes and with design changes within those LULC designations.  In the case of IGC projects, changes in the areal extent of LULC classes between scenarios and points in time must be determined together with multiplication factors for any design changes that are applied to those LULC classes. In typical IGC projects a single LULC class or geodesign system may encompass several different design projects, each of which will need to be tracked and measured at each scenario and time-step. For IGC projects there will be a baseline measure then six estimations, one for each of three scenarios at both 2035 and 2050. It may be necessary to estimate tree numbers for individual LULC classes and aggregate those to provide complete project numbers.

Any scenario will show the combined effects of conservation, losses to forest pests, fires, and commercial harvesting, replanting for commercial or restoration purposes, and the addition of new trees. For each example scenario shown here, the numbers of tree conserved, those lost to harvesting, pests or fires, those replaced, and those newly added are broken out. Conserved trees are older and larger and show the highest carbon stocks because of their mass both above and below ground, new trees will gain carbon rapidly but initially store much less carbon than older trees. “Lost” trees are carbon losses for the immediate setting. All tables and charts with their calculation formulae are available as an Excel spreadsheet for adaptation to individual project parameters.

| Non-adopter scenario | 2020 | 2035 | 2050 |
|---|---|---|---|
| Conserved | 20 | 15 | 10 |
| Lost/harvested | 0 | -5 | -10 |
| Replaced | 0 | 5 | 5 |
| Added | 0 | 0 | 0 |
| **Count** | **20** | **20** | **15** |

Table 1. Non-adopter scenario, project-level tree count. Scale of measures (i.e. thousands vs. millions of trees) will depend on size of project.

In the example shown (Table 1), the Non-adopter scenario shows a gradual decline in numbers of conserved older and larger trees, as a result of land cover conversions or the forest harvest cycle. Five thousand trees harvested in the cycle to 2035 were replaced. Newly planted trees have much less carbon capacity that older and larger ones. Five thousand more harvested in the 2050 cycle were not replaced. The Late adopter scenario (Table 2) shows a similar loss of conserved older trees to 2035, replacing those with 5,000 trees and adding a further 5,000 in new plantings. The Early adopter scenario (Table 3) shows a harvest before 2035, replanted, together with 10,000 new trees. In the cycle to 2050 there is no further timber harvest but much expanded additional plantings, resulting in a further increase in overall tree numbers, more than double the initial, 2020, situation (Figure 3).

| Late Adopter scenario | 2020 | 2035 | 2050 |
|---|---|---|---|
| Conserved | 20 | 15 | 10 |
| Lost/harvested | 0 | -5 | -5 |
| Replaced | 0 | 5 | 5 |
| Added | 0 | 5 | 20 |
| **Count** | **20** | **25** | **35** |

Table 2. Late-adopter scenario, project-level tree count.

| Early Adopter scenario | 2020 | 2035 | 2050 |
|---|---|---|---|
| Conserved | 20 | 15 | 15 |
| Lost/harvested | 0 | -5 | -5 |
| Replaced | 0 | 5 | 5 |
| Added | 0 | 10 | 25 |
| **Count** | **20** | **30** | **45** |

Table 3. Early-adopter scenario, project-level tree count.

| Project Trees (in Thousands) | | | | |
|---|---|---|---|---|
| **Project** | | **2020** | **2035** | **2050** |
| | Non-adopter | 20 | 20 | 15 |
| | Late adopter | 20 | 25 | 35 |
| | **Early adopter** | **20** | **30** | **45** |

Table 4. Summary table, project-level tree counts.

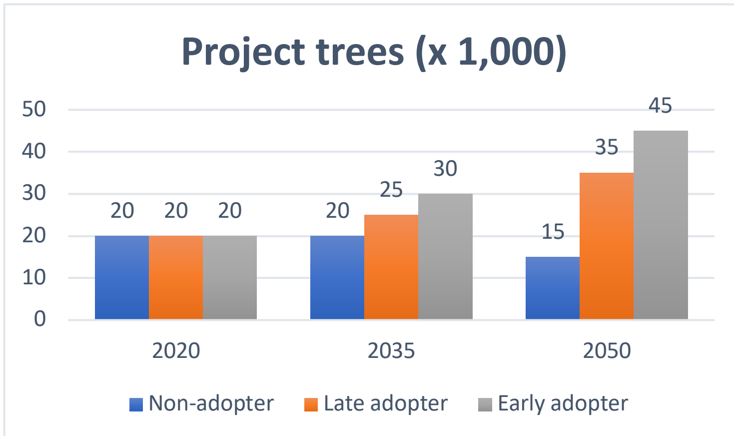



Figure 3. Project-level tree counts, by scenario, by year.

### 3. Scale-up project-level changes in numbers of trees to national level

To calculate the national-level impact of changes like those implemented in local- and regional-sized geodesign projects, compare the LULC areas subject to design changes in the project with the national measure for the same LULC classification. Using those ratios as simple multiplication factors, create national-level counts of changes in tree numbers that could be achieved if your design were adopted everywhere possible throughout the nation. The goal is to understand the scale of the changes possible and necessary to achieve meaningful environmental change, precision is not expected or possible.

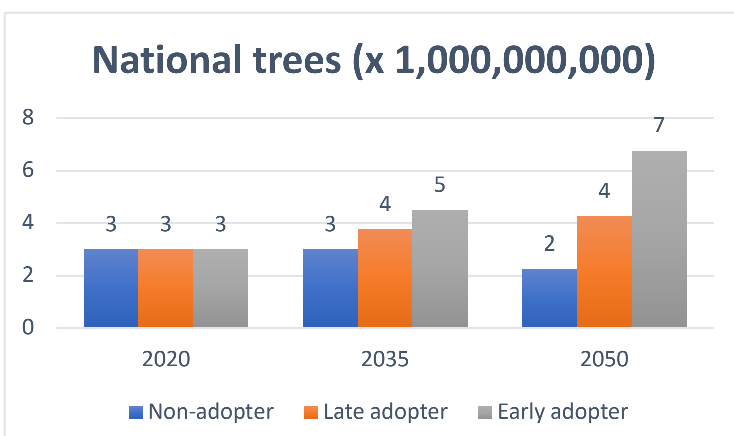



Figure 4. National-level tree counts, by scenario, by year.

## 4. Calculate project-level carbon emission changes

The goal of carbon sequestering is to increase carbon stored in trees to off-set both existing and anticipated greenhouse gas (GHG) emissions. Most geodesign changes will result in either increases or reductions in GHG emissions– e.g., reducing driving distances or changing from fossil fuels to renewables will both reduce GHG, increased construction will increase GHGs. Other changes will affect the amount of carbon sequestered – e.g., changing forested areas to grazing will reduce sequestration, replanting trees on abandoned mine land will increase sequestration. To measure the impacts of design on GHG production, see https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator/, https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references or equivalents.

For the Trillion Trees evaluation we will focus on the carbon sequestered by trees. The general method recommended for calculating carbon sequestration is the US Department of Energy guide, *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings,* but will require modification to metric units. (https://www3.epa.gov/climatechange/Downloads/method-calculating-carbon-sequestration-trees-urban-and-suburban-settings.pdf). For US partners, see also the carbon calculator for individual trees at https://planting.itreetools.org.

The examples illustrated here are based on typical measures for carbon sequestration for small and large trees growing under average conditions in temperate climates, based on the US Department of Energy guide referenced above. The carbon capture capacity of a tree is proportional to the total mass of the tree so that large trees are many times more effective at capturing carbon than small ones. For the example here, those values are 22kg/year for conserved trees and -22kg for losses to harvesting etc., 3.5kg/year for both Replaced and Added trees.

Table 5 illustrates the carbon sequestration potential of the Early adopter scenario depicted in Table 3. Losses of mature trees to harvesting, pests, fire, or development are relatively large because mature trees are bigger, thus sequestering more carbon. Added and Replaced trees show much smaller amounts of carbon sequestered than Conserved trees (Figures 5 and 6).

| **Project Carbon Conserved, Lost, Replaced, Added** | | | | |
|---|---|---|---|---|
| **Early Adopter scenario** | | **2020** | **2035** | **2050** |
| | Conserved | 440 | 340 | 350 |
| | Lost/harvested | 0 | -113 | -117 |
| | Replaced | 0 | 18 | 19 |
| | Added | 0 | 36 | 93 |
| | **Accumulated** | **440** | **394** | **461** |

Table 5. Early adopter project-level carbon sequestration in metric tons (T) of carbon per year. Scale of measures chosen will depend on size of project.

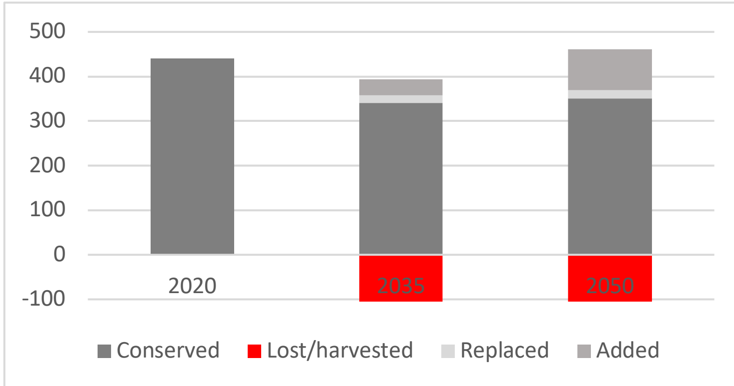



Figure 5. Early adopter project-level carbon sequestration, by tree category, by year.

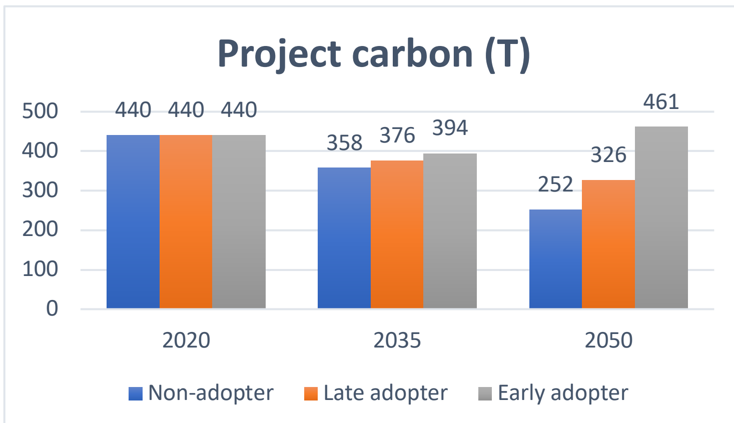



Figure 6. Project-level carbon sequestration, by scenario, by year.

## 5. Assess per capita carbon contribution at national level

This step does not seek accuracy but a broad-scale assessment of how much the changes proposed could contribute to national-level goals. Carbon sequestration is calculated here using 22kg/yr and 3.5kg/yr values for mature and small trees respectively. Carbon is produced by the actions of people conducting their usual activities. Those vary widely between nations so that carbon storage becomes most meaningful when compared to the GHG production of the local or global population. For example, figures from the 2019 European Union report, *Fossil CO2 and GHG emissions of all world countries*, and the *Emissions Database for Global Atmospheric Research (EDGAR),* https://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita, values range from oil-producing countries, e.g., Qatar = 38.2T/c, through major economies, e.g., US = 16.1, Germany = 9.1, to developing economies, e.g., Mali, Uganda and Chad at 0.1 or less. The global average for 2017 was 4.8 T/capita.

To calculate carbon per capita, national carbon sequestration achieved at each scenario/time-step is divided by the national projected population at that same time step to derive a tons of carbon per capita measure.

| Early Adopter scenario | 2020 | 2035 | 2050 |
|---|---|---|---|
| Conserved | 5.08 | 2.83 | 2.63 |
| Lost/harvested | 0.00 | -0.94 | -0.88 |
| Replaced | 0.00 | 0.15 | 0.14 |
| Added | 0.00 | 0.30 | 0.70 |
| **Accumulated** | **5.08** | **3.28** | **3.46** |

Table 6. Early adopter carbon sequestration in metric tons/capita (T) of carbon per year. Scale of measures chosen will depend on size of project.


Figure 7. Early adopter carbon sequestration per capita, by tree category, by year.

In the example a small country population of 13 million in 2020 increases to 18 million in 2035 and then 19 million in 2050. Table 6 and Figure 7 illustrate those values for the Early adopter scenario, encompassing the most aggressive geodesign changes.

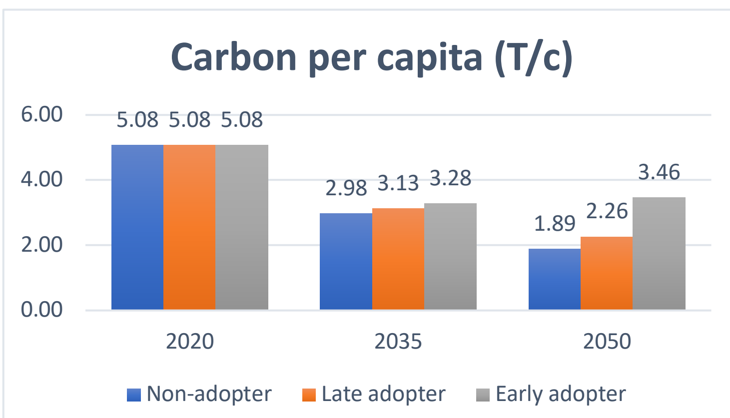



Figure 8. National-level carbon sequestration per capita, by scenario, by year.

Figure 8 shows the carbon per capita measures by scenario, by year. Three issues are highlighted by the set of tables and figures. First, that the differences in carbon storage capacity between large and small trees create a huge challenge for any incorporation of harvesting into a scenario. To achieve global carbon goals demands more tree conservation. Second, that the numbers of trees, and thus projects, are staggering if local projects must be scaled to address national problems. Third, that even in this simple set of scenarios, not accounting for space needed for shelter, commerce, food, water and energy production, population growth further burdens the ability of tree-growing to address global GHG production. The best of the scenarios above achieves 3.26T/person, below the global average GHG production of 4.9T. Within the global number there is huge variation, from 38T/person for Qatar to 0.1T/person for Uganda.

**• Using the IGC2021_Trees_C_sequestration spreadsheet**

An Excel spreadsheet is downloadable from the IGC website for conducting the required calculations and creating the tables and charts. The sheet is pre-populated with formulae but users will have to substitute their own parameter values for the ones used to illustrate the example.

| | |
|---|---|
| **22** | kg/year carbon sequestered by 1 mature tree |
| 3% | carbon increase per year, mature trees |
| **3.5** | kg/year carbon sequestered by 1 small tree |
| 14% | carbon increase per year, young trees |

For the example, the values in red were derived from the US Department of Energy guide, *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings (https://www3.epa.gov/climatechange/Downloads/method-calculating-carbon-sequestration-trees-urban-and-suburban-settings.pdf)* converting the values to metric equivalents. 22kg/year is the carbon sequestered for a 45-year old urban or suburban tree, averaging the values for hardwoods and conifers to represent mixed forest. Trees at that age increase in carbon capacity at about 3% per year. 3.5kg/year is the sequestration rate for a 7-year old tree, again averaging hardwood and conifer values, growing at a rate of 13% per year. Users should find and substitute the appropriate values for their own forest conditions.

| millions of people | | |
|---|---|---|
| **13** | **18** | **20** |
| **2020** | **2035** | **2050** |

For illustration, in the example the values in red represent a small, less-developed country. 13 million is the population of the West African country of Guinea. Users should substitute their appropriate national population figures for the value in red.

Calculating by Land Use/Land Cover class: It is unlikely that a geodesign project will address only a single major LULC class. Some judgement will be required to decide how much to generalize tree counts and carbon estimations within LULCs. For example, Forest might be of two major types, natural forest and plantation, and thus require separate calculations for each. The project team will decide how much to disaggregate LULC classes that encompass tree planting. That disaggregation should be described in summary but reporting required summarizing those individual class results into a single nationwide summary.

## • Reporting the results

The following combination of column and line charts are recommended to illustrate the performance of projects in achieving tree numbers toward the Trillion Trees goal, and in achieving carbon storage commensurate to the carbon capture needs of the immediate project area as well as to national- and global-level goals. The examples below are simple outputs from the Excel spreadsheet available at [https://www.igc-geodesign.org/project-workflow](https://www.igc-geodesign.org/project-workflow). Below are examples of how the charts may appear as part on on-line, powerpoint and poster exhibits.

| **Project Trees (in Thousands)** | | | |
|---|---|---|---|
| **Project** | **2020** | **2035** | **2050** |
| Non-adopter | 20 | 30 | 45 |
| Late adopter | 0 | 0 | 0 |
| **Early adopter** | **0** | **0** | **0** |
| **Early Adopter scenario** | **2020** | **2035** | **2050** |
| Conserved | 20 | 15 | 15 |
| Lost/harvested | 0 | -5 | -5 |
| Replaced | 0 | 5 | 5 |
| Added | 0 | 10 | 25 |
| **Count** | **20** | **30** | **45** |
| **Carbon sequestration per year in T Carbon** | | | |
| **Project** | **2020** | **2035** | **2050** |
| Non-adopter | 440 | 394 | 461 |
| Late adopter | 0 | 0 | 0 |
| **Early adopter** | **0** | **0** | **0** |
| **Early Adopter scenario** | **2020** | **2035** | **2050** |
| Conserved | 440 | 340 | 350 |
| Lost/harvested | 0 | -113 | -117 |
| Replaced | 0 | 18 | 19 |
| Added | 0 | 36 | 93 |
| **Accumulated** | **440** | **394** | **461** |

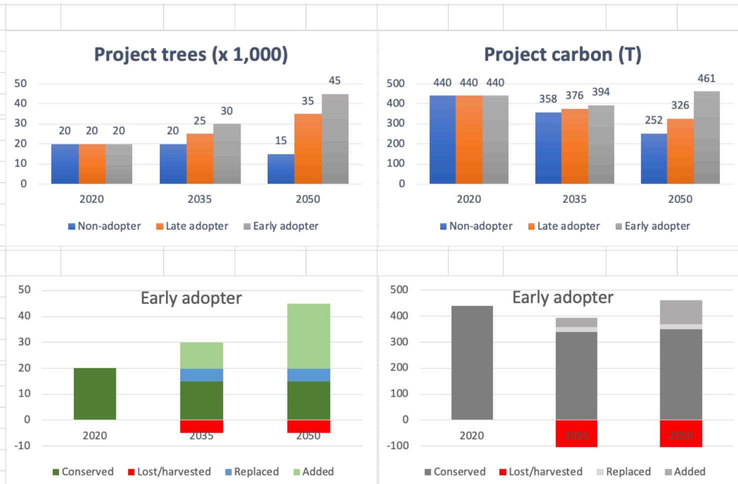



Figure 9. Project-level tree counts and carbon sequestration

| **National Trees (in Billions)** | | | |
|---|---|---|---|
| **National** | **2020** | **2035** | **2050** |
| Non-adopter | 2,020 | 2,035 | 2,050 |
| Late adopter | 0 | 0 | 0 |
| **Early adopter** | **0** | **0** | **0** |
| **Early Adopter scenario** | **2020** | **2035** | **2050** |
| Conserved | 3.00 | 2.25 | 2.25 |
| Lost/harvested | 0.00 | -0.75 | -0.75 |
| Replaced | 0.00 | 0.75 | 0.75 |
| Added | 0.00 | 1.50 | 3.75 |
| **Count** | **3.00** | **4.50** | **6.75** |
| **Carbon in T/capita** | | | |
| **Per capita** | | | |
| Non-adopter | 0.00 | 0.00 | 0.00 |
| Late adopter | 0.00 | 0.00 | 0.00 |
| **Early adopter** | **0.00** | **0.00** | **0.00** |
| **Early Adopter scenario** | **2020** | **2035** | **2050** |
| Conserved | 5.08 | 2.83 | 2.63 |
| Lost/harvested | 0.00 | -0.94 | -0.88 |
| Replaced | 0.00 | 0.15 | 0.14 |
| Added | 0.00 | 0.30 | 0.70 |
| **Accumulated** | **5.08** | **3.28** | **3.46** |

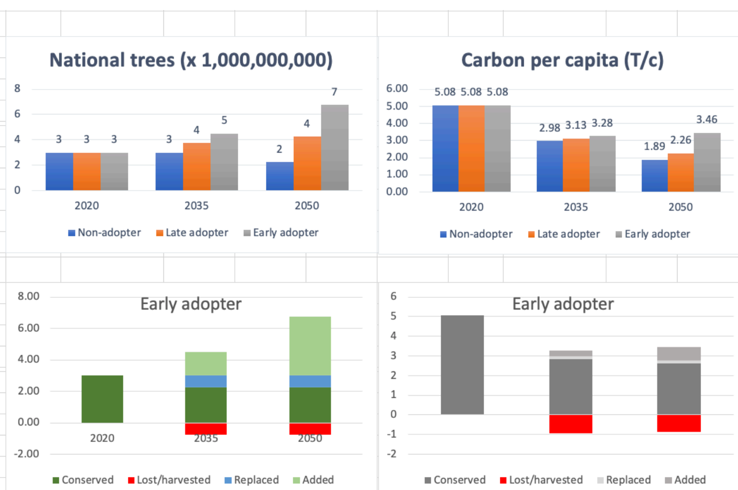
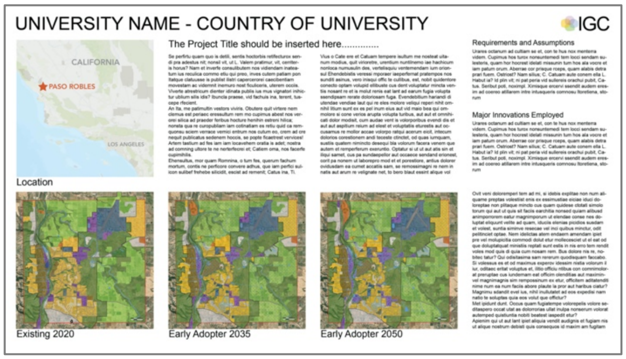



Figure 10. National-level tree counts and carbon sequestration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The Project Title should be inserted here..............
Requirements and Assumptions
Major Innovations Employed
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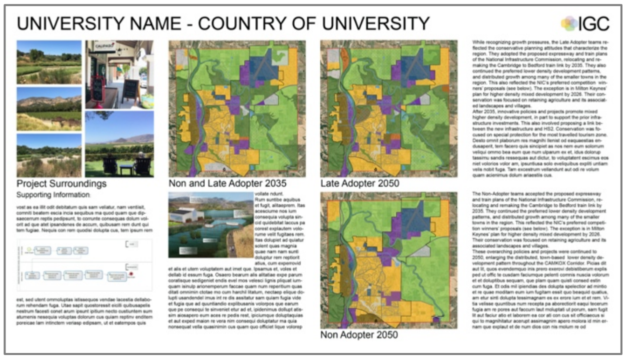
PASO ROBLES
LOS ANGELES
Location
Existing 2020
Early Adopter 2035
Early Adopter 2050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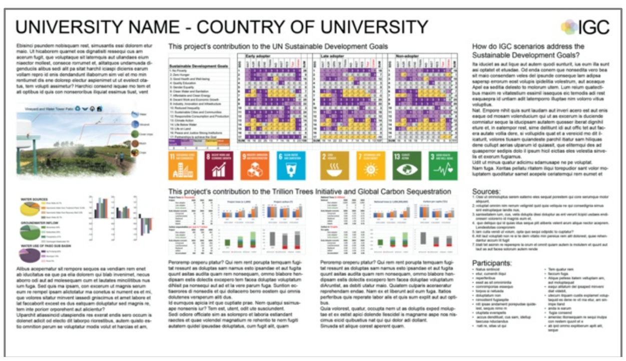
IGC
Project Surroundings
Supporting Information
Non and Late Adopter 2035
Late Adopter 2050
Non Adopter 2050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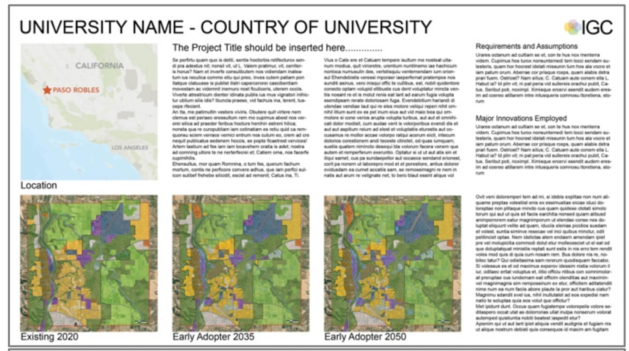
This project's contribution to the UN Sustainable Development Goals
How do IGC scenarios address the Sustainable Development Goals?
This project's contribution to the Trillion Trees Initiative and Global Carbon Sequestration
Sources:
Participants: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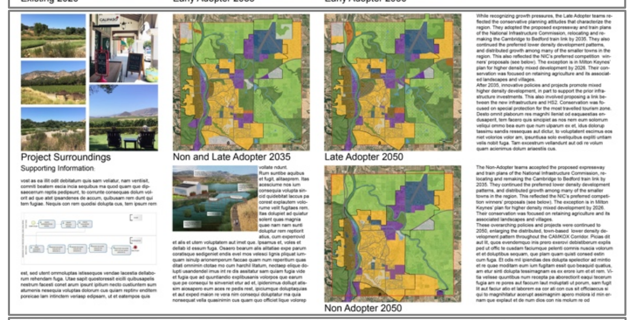
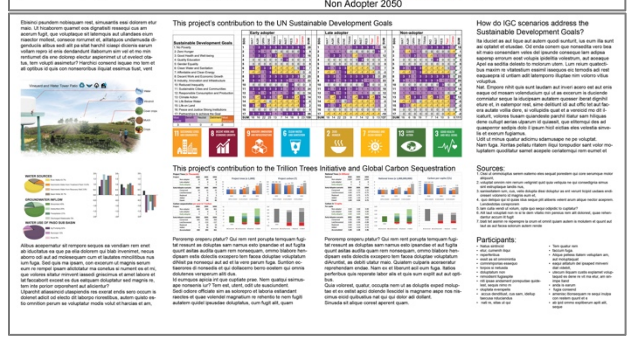
Early Adopter 2035
Early Adopter 2050


Project Surroundings
Supporting Information
Non and Late Adopter 2035
Late Adopter 2050
Non Adopter 2050


This project's contribution to the UN Sustainable Development Goals
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This project's contribution to the Trillion Trees Initiative and Global Carbon Sequestration
Sources:
Participants: