problem_set_4

April 15, 2024

1 Problem Set #4

1.1 Ryan McWay

1.2 Question 1

I ran the crop pollination model. This models pollination by four bee species. Pollination is important for crop production for 87 of the most important crops by facilitating the asexual reproduction of the floral process for crops. Humans need food to eat, so pollination supports the agricultural food cycle.

1.3 Question 2

To measure the quantity of the pollinator ecosystem service, we are aiming to determine the pollinator supply and abudnance. If we wish to go further, we can use this as an input to the farm information to determine the on-farm abdundance and crop yield from pollinator inputs. To estimate pollinator supply (orgination), we need to know for a pixel x for species s the accessible floral resource index, habitat nesting suitability, and relative species abudnance index. These first two components are calculated through a formula of other inputs described in Q3. To estimate pollinator abundance (activity), we can again rely on a formula to estimate through the relative abudnance, accessible floral resources, and now the pollinator supply.

1.4 Question 3

The input values are a LULC map, a biophysical table to determine nesting of pollinators suitability and floral resources across spring and summer for each land use type, and a pollinator guild table to tell us what seasons the pollinator is active, their nesting preferences, mean flight distance, and relative abundance of the species. Optionally, you can include a shapefile for a farm to see how the pollinator will react with a specific farmers inptus.

1.5 Question 4

[ ]:
```
# InVEST Crop Pollination Script

import logging
import sys

import natcap.invest.pollination
import natcap.invest.utils
```

```
LOGGER = logging.getLogger(__name__)
root_logger = logging.getLogger()

handler = logging.StreamHandler(sys.stdout)
formatter = logging.Formatter(
    fmt=natcap.invest.utils.LOG_FMT,
    datefmt='%m/%d/%Y %H:%M:%S ')
handler.setFormatter(formatter)
logging.basicConfig(level=logging.INFO, handlers=[handler])

args = {
    'farm_vector_path': '',
    'guild_table_path': 'C:\\Users\\ryanm\\Dropbox '
                        ␣
 ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\guild_table.
 ↪csv',
    'landcover_biophysical_table_path': 'C:\\Users\\ryanm\\Dropbox '
                                        ␣
 ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\landcover_biophysical_tabl
 ↪csv',
    'landcover_raster_path': 'C:\\Users\\ryanm\\Dropbox '
                             ␣
 ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\landcover.
 ↪tif',
    'n_workers': '-1',
    'results_suffix': '',
    'workspace_dir': 'C:\\Users\\ryanm\\Dropbox '
                     ␣
 ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\output',
}

if __name__ == '__main__':
    natcap.invest.pollination.execute(args)
```

```
04/15/2024 15:35:15  (natcap.invest.pollination)
pollination._parse_scenario_variables(1212) INFO Checking to make sure guild
table has all expected headers
04/15/2024 15:35:15  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:15  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-5
(stats_worker), started daemon 2268)>
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
```

```
result.
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-6
(stats_worker), started daemon 8788)>
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-7
(stats_worker), started daemon 428)>
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-8
(stats_worker), started daemon 21540)>
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-9
(stats_worker), started daemon 1908)>
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:16  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:16  (taskgraph.Task) Task.add_task(653) INFO A task was created
that had an identical args signature sans target paths, but a different
target_path_list of the same length. To avoid recomputation, dynamically adding
previous Task (calculate_habitat_nesting_apis2 (3)) as a dependent task to this
one (calculate_habitat_nesting_bombus2 (5)).
04/15/2024 15:35:17  (taskgraph.Task) Task.is_precalculated(1252) INFO not
precalculated (calculate_habitat_nesting_bombus2 (5)), Task hash exists, but
```

```
there are these mismatches: Recorded path not in target path list
c:\users\ryanm\dropbox (personal)\github\base_data\invest_sample_data\pollinatio
n\output\intermediate_outputs\habitat_nesting_index_apis2.tif
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-10
(stats_worker), started daemon 11156)>
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-11
(stats_worker), started daemon 17392)>
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-12
(stats_worker), started daemon 22000)>
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-13
(stats_worker), started daemon 18468)>
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:17  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-14
(stats_worker), started daemon 27632)>
```

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04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (taskgraph.Task) Task.add_task(653) INFO A task was created
that had an identical args signature sans target paths, but a different
target_path_list of the same length. To avoid recomputation, dynamically adding
previous Task (calculate_foraged_flowers_apis_spring (7)) as a dependent task to
this one (calculate_foraged_flowers_apis2_spring (9)).
04/15/2024 15:35:18  (taskgraph.Task) Task.is_precalculated(1252) INFO not
precalculated (calculate_foraged_flowers_apis2_spring (9)), Task hash exists,
but there are these mismatches: Recorded path not in target path list
c:\users\ryanm\dropbox (personal)\github\base_data\invest_sample_data\pollinatio
n\output\intermediate_outputs\foraged_flowers_index_apis_spring.tif
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-15
(stats_worker), started daemon 6924)>
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (taskgraph.Task) Task.add_task(653) INFO A task was created
that had an identical args signature sans target paths, but a different
target_path_list of the same length. To avoid recomputation, dynamically adding
previous Task (calculate_foraged_flowers_apis_summer (8)) as a dependent task to
this one (calculate_foraged_flowers_apis2_summer (9)).
04/15/2024 15:35:18  (taskgraph.Task) Task.is_precalculated(1252) INFO not
precalculated (calculate_foraged_flowers_apis2_summer (9)), Task hash exists,
but there are these mismatches: Recorded path not in target path list
c:\users\ryanm\dropbox (personal)\github\base_data\invest_sample_data\pollinatio
n\output\intermediate_outputs\foraged_flowers_index_apis_summer.tif
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-16
(stats_worker), started daemon 7948)>
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
```

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geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-17
(stats_worker), started daemon 4196)>
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-18
(stats_worker), started daemon 30332)>
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (taskgraph.Task) Task.add_task(653) INFO A task was created
that had an identical args signature sans target paths, but a different
target_path_list of the same length. To avoid recomputation, dynamically adding
previous Task (calculate_foraged_flowers_bombus_spring (9)) as a dependent task
to this one (calculate_foraged_flowers_bombus2_spring (11)).
04/15/2024 15:35:18  (taskgraph.Task) Task.is_precalculated(1252) INFO not
precalculated (calculate_foraged_flowers_bombus2_spring (11)), Task hash exists,
but there are these mismatches: Recorded path not in target path list
c:\users\ryanm\dropbox (personal)\github\base_data\invest_sample_data\pollinatio
n\output\intermediate_outputs\foraged_flowers_index_bombus_spring.tif
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-19
(stats_worker), started daemon 16744)>
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:18  (taskgraph.Task) Task.add_task(653) INFO A task was created
that had an identical args signature sans target paths, but a different
target_path_list of the same length. To avoid recomputation, dynamically adding
previous Task (calculate_foraged_flowers_bombus_summer (10)) as a dependent task
to this one (calculate_foraged_flowers_bombus2_summer (11)).
04/15/2024 15:35:18  (taskgraph.Task) Task.is_precalculated(1252) INFO not
precalculated (calculate_foraged_flowers_bombus2_summer (11)), Task hash exists,
but there are these mismatches: Recorded path not in target path list
c:\users\ryanm\dropbox (personal)\github\base_data\invest_sample_data\pollinatio
n\output\intermediate_outputs\foraged_flowers_index_bombus_summer.tif
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
```

```
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:18  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-20
(stats_worker), started daemon 2888)>
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-21
(stats_worker), started daemon 16896)>
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:19  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:20  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
floral_resources_apis.tif
04/15/2024 15:35:20  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:20  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on floral_resources_apis.tif
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-24
(stats_worker), started daemon 5316)>
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:21  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:22  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
```

```
convolve_ps_apis.tif
04/15/2024 15:35:22  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:22  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on convolve_ps_apis.tif
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-27
(stats_worker), started daemon 6848)>
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:23  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-28
(stats_worker), started daemon 13744)>
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-29
(stats_worker), started daemon 14972)>
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:24  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:25  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
floral_resources_apis2.tif
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
```

```
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on floral_resources_apis2.tif
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-32
(stats_worker), started daemon 22352)>
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:26  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:27  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:27  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:28  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
convolve_ps_apis2.tif
04/15/2024 15:35:28  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:28  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on convolve_ps_apis2.tif
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-35
(stats_worker), started daemon 3516)>
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-36
(stats_worker), started daemon 15684)>
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:29  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
```

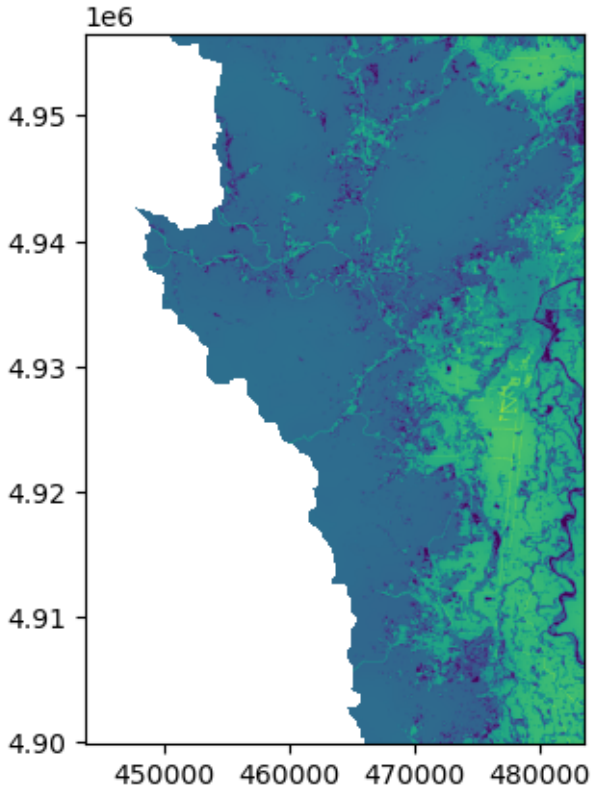
```
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-37
(stats_worker), started daemon 8400)>
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:30  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 192 sent to workers, wait for worker
results
04/15/2024 15:35:35  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
floral_resources_bombus.tif
04/15/2024 15:35:35  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:35  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3357) INFO convolution nodata normalizer approximately
2.6% complete on floral_resources_bombus.tif
04/15/2024 15:35:35  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on floral_resources_bombus.tif
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-40
(stats_worker), started daemon 22656)>
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:36  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 192 sent to workers, wait for worker
results
04/15/2024 15:35:41  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3316) INFO convolution worker approximately 93.8%
complete on convolve_ps_bombus.tif
04/15/2024 15:35:41  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
convolve_ps_bombus.tif
04/15/2024 15:35:42  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
```

```
04/15/2024 15:35:42  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on convolve_ps_bombus.tif
04/15/2024 15:35:42  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:42  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-43
(stats_worker), started daemon 13376)>
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-44
(stats_worker), started daemon 27320)>
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-45
(stats_worker), started daemon 25984)>
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:43  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:44  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:44  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:45  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
floral_resources_bombus2.tif
04/15/2024 15:35:45  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on floral_resources_bombus2.tif
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
```

```
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-48
(stats_worker), started daemon 4152)>
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3209) INFO starting convolve
04/15/2024 15:35:46  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3257) INFO 48 sent to workers, wait for worker results
04/15/2024 15:35:48  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3321) INFO convolution worker 100.0% complete on
convolve_ps_bombus2.tif
04/15/2024 15:35:48  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3329) INFO need to normalize result so nodata values
are not included
04/15/2024 15:35:48  (pygeoprocessing.geoprocessing)
geoprocessing.convolve_2d(3365) INFO convolution nodata normalize 100.0%
complete on convolve_ps_bombus2.tif
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-51
(stats_worker), started daemon 15936)>
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:49  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-52
(stats_worker), started daemon 5596)>
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-53
(stats_worker), started daemon 17596)>
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
```

```
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(495) INFO starting stats_worker
04/15/2024 15:35:50  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(501) INFO started stats_worker <Thread(Thread-54
(stats_worker), started daemon 1660)>
04/15/2024 15:35:51  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(580) INFO 100.0% complete
04/15/2024 15:35:51  (pygeoprocessing.geoprocessing)
geoprocessing.raster_calculator(583) INFO Waiting for raster stats worker
result.
```

[ ]:
```
# Create a graph of the tif file.
import rasterio
from rasterio.plot import show
fp = r'C:\\Users\\ryanm\\Dropbox '␣
  ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\output\\total_pollinator_a
  ↪tif'
img = rasterio.open(fp)
show(img)
```



[ ]: <Axes: >

1.6 Question 5

I changed the input value for relative abundance for the four bee species in the guild table.

[ ]:
```
# Change arguments for biophyscial values
import pandas as pd
guild_table = pd.read_csv('C:\\Users\\ryanm\\Dropbox '
                          ␣
 ↪'(Personal)\\Github\\base_data\\invest_sample_data\\pollination\\guild_table.
 ↪csv')
# Create abundance levels from 0% to 100%
rate_1 = [0, 0, 0, 0]
rate_2 = [0.1, 0.1, 0.1, 0.1]
rate_3 = [0.2, 0.2, 0.2, 0.2]
rate_4 = [0.3, 0.3, 0.3, 0.3]
rate_5 = [0.4, 0.4, 0.4, 0.4]
rate_6 = [0.5, 0.5, 0.5, 0.5]
rate_7 = [0.6, 0.6, 0.6, 0.6]
rate_8 = [0.7, 0.7, 0.7, 0.7]
rate_9 = [0.8, 0.8, 0.8, 0.8]
rate_10 = [0.9, 0.9, 0.9, 0.9]
rate_11 = [1, 1, 1, 1]

guild_table = guild_table.rename(columns= {"relative_abundance":␣
 ↪"relative_abundance_og"})
guild_table = guild_table.assign(relative_abundance_0 = rate_1,␣
 ↪relative_abundance_1 = rate_2, relative_abundance_2 = rate_3,
                                 relative_abundance_3 = rate_4,␣
 ↪relative_abundance_4 = rate_5, relative_abundance_5 = rate_6,
                                 relative_abundance_6 = rate_7,␣
 ↪relative_abundance_7 = rate_8, relative_abundance_8 = rate_9,
                                 relative_abundance_9 = rate_10,␣
 ↪relative_abundance_10 = rate_11)
guild_table
```

[ ]:
```
   SPECIES  nesting_suitability_cavity_index  \
0     Apis                                 1
1   Bombus                                 1
2    Apis2                                 0
3  Bombus2                                 0

   nesting_suitability_ground_index  foraging_activity_spring_index  \
0                                 1                             1.0
1                                 0                             0.8
```

```
2                                 1                                 1.0
3                                 1                                 0.8

   foraging_activity_summer_index  alpha  relative_abundance_og  \
0                               1    500                   0.75
1                               1   1500                   1.00
2                               1    750                   0.75
3                               1    750                   1.00

   relative_abundance_0  relative_abundance_1  relative_abundance_2  \
0                     0                   0.1                   0.2
1                     0                   0.1                   0.2
2                     0                   0.1                   0.2
3                     0                   0.1                   0.2

   relative_abundance_3  relative_abundance_4  relative_abundance_5  \
0                   0.3                   0.4                   0.5
1                   0.3                   0.4                   0.5
2                   0.3                   0.4                   0.5
3                   0.3                   0.4                   0.5

   relative_abundance_6  relative_abundance_7  relative_abundance_8  \
0                   0.6                   0.7                   0.8
1                   0.6                   0.7                   0.8
2                   0.6                   0.7                   0.8
3                   0.6                   0.7                   0.8

   relative_abundance_9  relative_abundance_10
0                   0.9                     1
1                   0.9                     1
2                   0.9                     1
3                   0.9                     1
```

[ ]:
```
# Interate over this change in

# Justin, I was struggling to do this. Perhaps I needed to make ten different␣
 ↪datasets with the same variable name instead of 1 dataset.
# It seems like the key paramter to change here is␣
 ↪_RELATIVE_SPECIES_ABUNDANCE_FIELD = 'relative_abundance' and swap out what␣
 ↪is being called.

# Update the guild-table-path
# args = {
#     'guild_table_path': guild_table,
# }

# if __name__ == '__main__':
```

```
#     natcap.invest.pollination.execute(args)
```