SANBI Biodiversity for Life
South African National Biodiversity Institute

Ecosystem Area Index (EAI) for South Africa: Metadata (version 1)

SANBI Report # 8613 (http://hdl.handle.net/20.500.12143/8613)

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Prepared by

National Biodiversity Assessment Unit; South African National Biodiversity Institute

Purpose

To track habitat loss at a national scale, over time, by measuring changes in the natural remaining area (extent) of terrestrial ecosystem types. Habitat loss is key driver of global biodiversity loss where natural ecosystems are completely lost due to human activities such as the establishment of croplands, settlements, infrastructure, dams, mines and plantation forestry (using non-native tree species).

Definition

The Ecosystem Area Index (EAI) [1] measures changes in ecosystem area (extent) towards ecosystem collapse. The EAI is the geometric mean of the proportion of ecosystem area remaining over a given timeframe relative to the initial area and an ecosystem-specific collapse threshold. It uses data on ecosystem area and area-based collapse threshold as defined based on IUCN Red List of Ecosystems risk assessments.

Ecosystems are defined based on the geographic distribution, native biotic assemblage or ecological community, the environmental conditions that support them, and the processes and interactions among components; in South Africa terrestrial ecosystems are drawn from the national vegetation map [2,3]. The EAI was designed to capture trends in ecosystem area towards or away from ecosystem collapse, where a value of 1 indicates no loss of area, and a value of 0 indicates complete loss of area. Change in ecosystem area is important to measure because area is strongly related to the capacity of an ecosystem to support biodiversity, ecological processes and thus the provision of ecosystem services.

Current Index

The Ecosystem Areas Index (EAI) for South Africa showed an 8% decline between 1990 and 2020, from 0.755 to 0.699 (Figure 1). In the Indian Ocean Coastal Belt biome there has been a 20% decline in the EAI between 1990 and 2020, despite already having less than 50% of its original extent by 1990. The arid Nama Karoo and Succulent Karoo biomes show less decline than more mesic biomes (Figure 2).

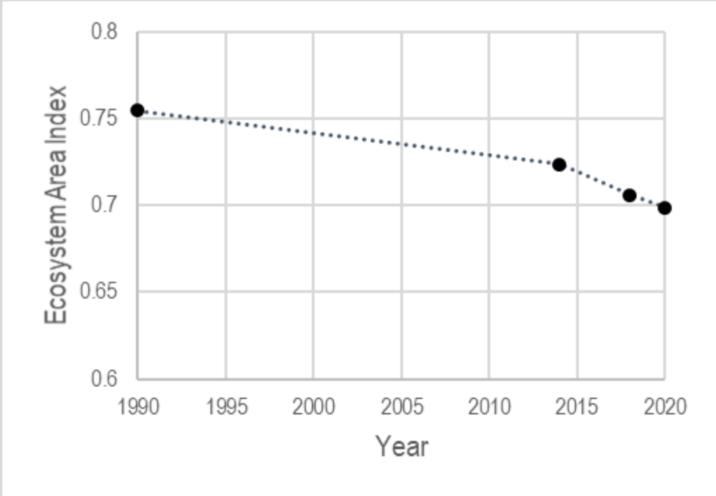

Figure 1. Ecosystem Area Index for South African terrestrial ecosystem types 1990-2020

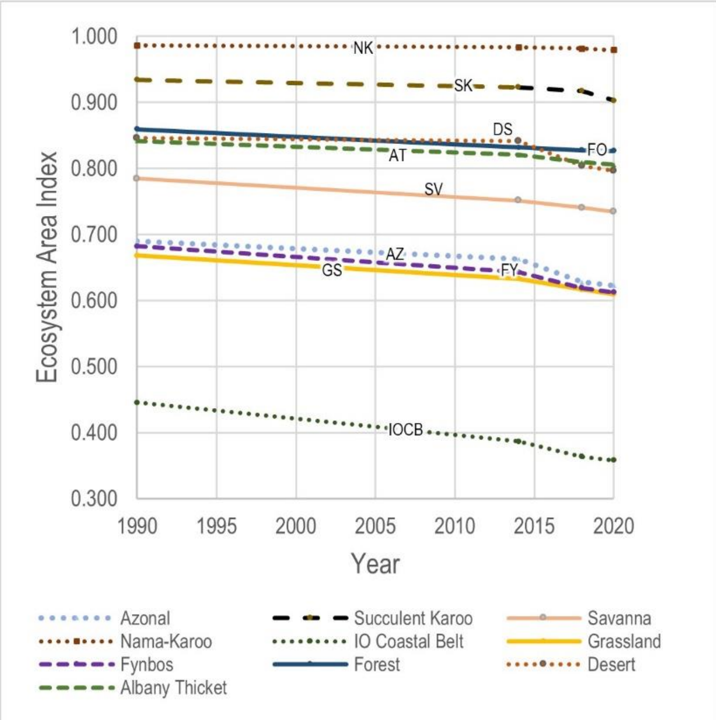

Figure 2. Ecosystem Area Index for South African terrestrial biomes 1990-2020

Table 1. Ecosystem Area Index values for South Africa's biomes.

Biome	1990	2014	2018	2020
Azonal	0.690	0.662	0.628	0.623
Succulent Karoo	0.934	0.923	0.917	0.903
Savanna	0.784	0.752	0.741	0.735
Nama-Karoo	0.986	0.983	0.982	0.979
Io Coastal Belt	0.445	0.387	0.364	0.358
Grassland	0.668	0.633	0.617	0.610
Fynbos	0.682	0.643	0.619	0.613
Forest	0.859	0.832	0.828	0.827
Desert	0.846	0.842	0.804	0.797
Albany Thicket	0.842	0.820	0.809	0.806
OVERALL	0.755	0.723	0.706	0.699

Reference Value

Calculated in 2022 using 2020 input data

Unit of Measure

Index 0-1

Data Scale

National

Data Required

A) Vegetation Map of South Africa Lesotho and Swaziland [2,3].
B) National Land Cover adjusted for time series analysis [4].

Methodology

National land-cover data sets for 1990, 2014, 2018 and 2020 [5] were modified to improve the representation of abandoned croplands and artificial water bodies and combined onto a common reference grid to allow for pixel-level comparisons [4]. The data sets were reclassified to a simplified binary scheme of natural vs. non-natural areas. The extent and rates of loss of natural vegetation cover were calculated for each of the 458 vegetation types delineated and described in the Vegetation of South Africa, Lesotho and Swaziland [2,3]. The remaining natural extent (RnE) of each vegetation type in 1990, 2014 and 2018 was calculated and expressed as a proportion of the original historical extent of the type prior to major land-cover changes in South Africa (i.e. circa 1750). The rate of recent habitat loss (RoL), between 1990 and 2018, was calculated and expressed as a proportion of the 1990 extent, divided by the difference in years between the time points. We then calculated the Ecosystem Area Index for South Africa by calculating the geometric mean of the RnE values for all 458 vegetation types in the country, and did the same for each biome, based on the equation $EAI = \sqrt[n]{a_1 . a_2 \ldots a_n}$ where *n* is the number of vegetation (ecosystem) types (458) and *a* is the proportion of natural habitat remaining for each ecosystem type at each time point [4]. Appendix 1 and 2 show the implementation of this workflow using a combination of ARCPY and Python.

Recommended Citation

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References

1. Rowland, J.A.; Nicholson, E.; Murray, N.J.; Keith, D.A.; Lester, R.E.; Bland, L.M. Selecting and applying indicators of ecosystem collapse for risk assessments. *Conserv. Biol.* **2018**, *32*, 1233–1245, doi:10.1111/cobi.13107.
2. Dayaram, A.; Harris, L.R.; Grobler, B.A.; van der Merwe, S.; Rebelo, A.G.; Powrie, L.W.; Vlok, J.H.J.; Desmet, P.G.; Qabaqaba, M.; Hlahane, K.M.; et al. Vegetation map of South Africa, Lesotho and Swaziland 2018: A description of changes since 2006. *Bothalia* **2019**, *49*, 1–11, doi:10.4102/ abc.v49i1.2452.
3. Mucina, L.; Rutherford, M.C. *The vegetation of South Africa, Lesotho and Swaziland*; Mucina, L., Rutherford, M.C., Eds.; Strelitzia.; South African National Biodiversity Institute: Pretoria, 2006; ISBN 978-1-919976-21-1.
4. Skowno, A.L.; Jewitt, D.; Slingsby, J.A. Rates and patterns of habitat loss across South Africa’s vegetation biomes. *S. Afr. J. Sci.* **2021**, *117*, 1–5, doi:https://doi.org/10.17159/sajs.2021/8182.
5. GeoTerraImage *Mpumalanga Provincial Land Cover (2017 Sentinel 2 imagery; 10m raster dataset)*; Pretoria, South Africa, 2018;

Appendix 1

Ecosystem Area Index Workflow PHASE 1 - Spatial Analysis (Version: 1.0, Date: 20/06/2022)
Prepared by: SANBI - National Biodiversity Assessment Unit (Environment: ARCGIS PRO 2.6, Python Notebook and Model Builder)

In [ ]:

```
import nbformat as nb
```

In [ ]:

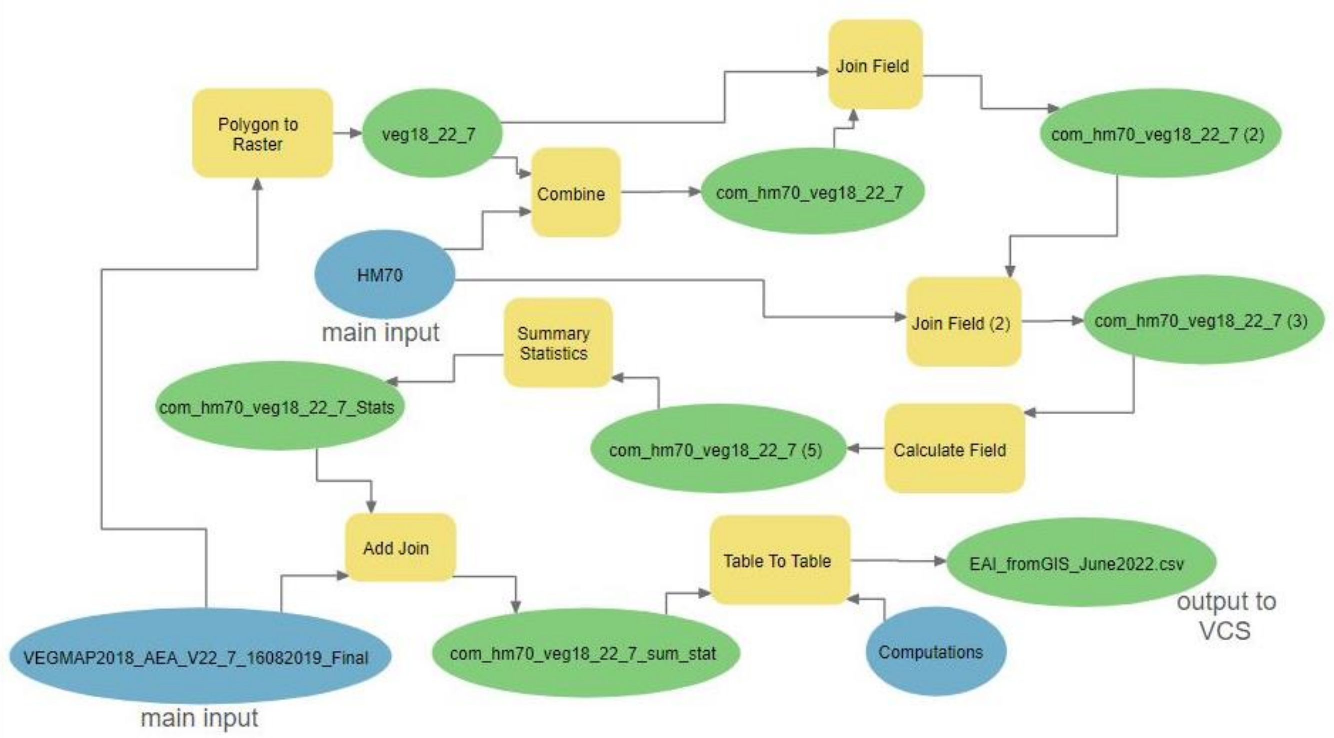
```
#Convert vegmap [veg18_22_7] to raster and combine with land cover change data [HM70]
#summarise and export to csv
#as markdown for display in VCS
import arcpy

def EAIworkflow20220615():  # EAI - workflow

    # To allow overwriting outputs change overwriteOutput option to True.
    arcpy.env.overwriteOutput = False

    # Check out any necessary licenses.
    arcpy.CheckOutExtension("spatial")

    # Model Environment settings
    with arcpy.EnvManager(cellSize=r"C:\*\HM70.gdb\HM70",
    extent="-894259.368935641 -3796095.05926977 816280.631064359 -2347485.05926977", outputCoordinateSystem=
    "PROJCS['SANBI AEA',GEOGCS['GCS_WGS_1984',DATUM['D_WGS_1984',SPHEROID['WGS_1984',6378137.0,298.257223563]],
    PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],PROJECTION['Albers'],PARAMETER['False_Easting',0.0],
    PARAMETER['False_Northing',0.0],PARAMETER['Central_Meridian',25.0],PARAMETER['Standard_Parallel_1',-24.0],
    PARAMETER['Standard_Parallel_2',-33.0],PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]",
                          snapRaster="HM70"):
        VEGMAP2018_AEA_V22_7_16082019_Final = "C:\\*\\HM70.gdb\\VEGMAP2018_AEA_V22_7_16082019_Final"
        HM70 = arcpy.Raster("C:\\*\\HM70.gdb\\HM70")
        Computations = "C:\\*\\Computations"
```




```
# Process: Polygon to Raster (Polygon to Raster) (conversion)
veg18_22_7 = "C:\\*\\working.gdb\\veg18_22_7"
with arcpy.EnvManager(outputCoordinateSystem="PROJCS['SANBI AEA',GEOGCS['GCS_WGS_1984',DATUM['D_WGS_1984',
SPHEROID['WGS_1984',6378137.0,298.257223563]],PRIMEM['Greenwich',0.0],UNIT['Degree',0.0174532925199433]],
PROJECTION['Albers'],PARAMETER['False_Easting',0.0],PARAMETER['False_Northing',0.0],PARAMETER['Central_Meridian',25.0],
PARAMETER['Standard_Parallel_1',-24.0],PARAMETER['Standard_Parallel_2',-33.0],
PARAMETER['Latitude_Of_Origin',0.0],UNIT['Meter',1.0]]"):
    arcpy.conversion.PolygonToRaster(in_features=VEGMAP2018_AEA_V22_7_16082019_Final, value_field="MAPCODE18",
    out_rasterdataset=veg18_22_7, cell_assignment="CELL_CENTER", priority_field="NONE",
    cellsize="C:\\*\\HM70.gdb\\HM70")

# Process: Combine (Combine) (sa)
com_hm70_veg18_22_7 = "C:\\*\\working.gdb\\com_hm70_veg18_22_7"
Combine = com_hm70_veg18_22_7
com_hm70_veg18_22_7 = arcpy.sa.Combine(in_rasters=[veg18_22_7, HM70])
```

```
        com_hm70_veg18_22_7.save(Combine)

        # Process: Join Field (Join Field) (management)
        com_hm70_veg18_22_7_2_ = arcpy.management.JoinField(in_data=com_hm70_veg18_22_7, in_field="veg18_22_7",
join_table=veg18_22_7,
        join_field="VALUE", fields=["MAPCODE18"])[0]

        # Process: Join Field (2) (Join Field) (management)
        com_hm70_veg18_22_7_3_ = arcpy.management.JoinField(in_data=com_hm70_veg18_22_7_2_, in_field="HM70",
        join_table=HM70, join_field="Value", fields=["COUNTRY", "LC90L1", "LC14L1", "LC18L1", "LC20L1"])[0]

        # Process: Calculate Field (Calculate Field) (management)
        com_hm70_veg18_22_7_4_ = arcpy.management.CalculateField(in_table=com_hm70_veg18_22_7_3_, field="KM2",
        expression="!Count! * 900/10000", expression_type="PYTHON3", code_block="", field_type="TEXT")[0]

        # Process: Summary Statistics (Summary Statistics) (analysis)
        com_hm70_veg18_22_7_Stats = "C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats"
        arcpy.analysis.Statistics(in_table=com_hm70_veg18_22_7_4_, out_table=com_hm70_veg18_22_7_Stats,
statistics_fields=[["KM2", "SUM"]],
        case_field=["COUNTRY", "LC14L1", "LC18L1", "LC20L1", "LC90L1", "MAPCODE18"])

        # Process: Add Join (Add Join) (management)
        com_hm70_veg18_22_7_sum_stat = arcpy.management.AddJoin(in_layer_or_view=com_hm70_veg18_22_7_Stats,
in_field="MAPCODE18",
        join_table=VEGMAP2018_AEA_V22_7_16082019_Final, join_field="MAPCODE18", join_type="KEEP_ALL")[0]

        # Process: Table To Table (Table To Table) (conversion)
        EAI_fromGIS_June2022_csv = arcpy.conversion.TableToTable(in_rows=com_hm70_veg18_22_7_sum_stat, out_path=Computations,
        out_name="EAI_fromGIS_June2022.csv", where_clause="",
        field_mapping="COUNTRY \"COUNTRY\" true true false 8000 Text 0 0,First,#,C:\\*\\working.gdb\\
        com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.COUNTRY,0,8000;LC14L1 \"LC14L1\" true true false 8000 Text 0
0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.LC14L1,0,8000;LC18L1 \"LC18L1\" true true false
8000 Text 0 0,First,#,
```

```
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.LC18L1,0,8000;LC20L1 \"LC20L1\" true true false
8000 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.LC20L1,0,8000;LC90L1 \"LC90L1\" true true false
8000 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.LC90L1,0,8000;MAPCODE18\"MAPCODE18\" true true
false 0 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.MAPCODE18,0,0;FREQUENCY \"FREQUENCY\" true true
false 0 Long 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,com_hm70_veg18_22_7_Stats.FREQUENCY,-1,-1;Name_18 \"Name_18\" true true
false 150 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,VEGMAP2018_AEA_V22_7_16082019_Final.Name_18,0,150;MAPCODE18_1
\"MAPCODE18\" true true false 50 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,VEGMAP2018_AEA_V22_7_16082019_Final.MAPCODE18,0,50;BIOME_18 \"BIOME_18\"
true true false 80 Text 0 0,First,#,
        C:\\*\\working.gdb\\com_hm70_veg18_22_7_Stats,VEGMAP2018_AEA_V22_7_16082019_Final.BIOME_18,0,80", config_keyword="")[0]

if __name__ == '__main__':
    # Global Environment settings
    with arcpy.EnvManager(scratchWorkspace=r"C:\Users\SkownoA\OneDrive -
sanbi.org.za\GIS\Monitoring\EcosystemAreaIndex\2020\GIS\working.gdb",
    workspace=r"C:\Users\SkownoA\OneDrive - sanbi.org.za\GIS\Monitoring\EcosystemAreaIndex\2020\GIS\working.gdb"):
        EAIworkflow20220615()
```

Appendix 2

Ecosystem Area Index Workflow PHASE 2 - Computation (Version: 1.0, Date: 20/06/2022)
Prepared by: SANBI - National Biodiversity Assessment Unit (Environment: Python Notebook - Visual Studio Code (Python 3.9.5)

In [ ]:

```
#import required packages
import pandas as pd
import numpy as np
import statistics as st
import matplotlib.pyplot as plt
import plotly_express as px
import nbformat as nb
```

Import CSV summary statistics generated in ARCGIS - [vegmap18.2.7 combined with HM70]
Summarise using pivot, year by year (1990, 2014, 2018, 2020)
Concatenate these tables into one summary table

In [ ]:

```
# import csv generated in ARCGIS
df = pd.read_csv (r'C:\\Users\\SkownoA\\OneDrive - 
sanbi.org.za\\GIS\\Monitoring\\EcosystemAreaIndex\\2020\\Computations\\EAI_fromGIS_June2022.csv')
```

In [ ]:

```
#pivot summary with vegetype name, code and biome for 1990
pt90 = pd.pivot_table(df, values="SUM_KM2", index=["MAPCODE18", "BIOME_18", "Name_18"], columns=["LC90L1"], aggfunc=np.sum)
pt90.reset_index()
pt90.columns = ['nat90', 'notnat90']
```

In [ ]:

```
#pivot summary with vegetype name, code and biome for 2014
pt14 = pd.pivot_table(df, values="SUM_KM2", index=["MAPCODE18","BIOME_18","Name_18"], columns=["LC14L1"],aggfunc=np.sum)
pt14.reset_index()
pt14.columns = ['nat14', 'notnat14']
```

In [ ]:

```
#pivot summary with vegetype name, code and biome for 2018
pt18 = pd.pivot_table(df, values="SUM_KM2", index=["MAPCODE18","BIOME_18","Name_18"], columns=["LC18L1"],aggfunc=np.sum)
```

```
pt18.reset_index()
pt18.columns = ['nat18', 'notnat18']
```

In [ ]:

```
#pivot summary with vegetype name, code and biome for 2020
pt20 = pd.pivot_table(df, values="SUM_KM2", index=["MAPCODE18","BIOME_18","Name_18"], columns=["LC20L1"],aggfunc=np.sum)
pt20.reset_index()
pt20.columns = ['nat20', 'notnat20']
```

In [ ]:

```
# concatenate to one table
pt90to20 = pd.concat([pt90, pt14, pt18, pt20], axis=1)
```

Add and compute new coloum showing the proportion natural habitat remaining for each ecosystem type

In [ ]:

```
# add coloum and compute
pt90to20[1990] = (pt90to20["nat90"] / (pt90to20["nat90"] + pt90to20["notnat90"] ))
pt90to20[2014] = (pt90to20["nat14"] / (pt90to20["nat14"] + pt90to20["notnat14"]))
pt90to20[2018] = (pt90to20["nat18"] / (pt90to20["nat18"] + pt90to20["notnat18"]))
pt90to20[2020] = (pt90to20["nat20"] / (pt90to20["nat20"] + pt90to20["notnat20"]))
#display first three rows of dataframe
pt90to20.head(3)
```

Out[ ]:

			nat90	**notnat90**	**nat14**	**notnat14**	**nat18**	**notnat18**	**nat20**	**notnat20**	**1990**	**2014**	**2018**	**2020**
MAPCODE18	**BIOME_18**	**Name_18**												
AT15	**Albany Thicket**	**Albany Arid Thicket**	1459.80	1.44	1459.80	1.44	1459.35	1.89	1459.35	1.89	0.999015	0.999015	0.998707	0.998707
AT16	**Albany Thicket**	**Albany Bontveld**	5165.91	210.15	5152.23	223.83	5128.47	247.59	5124.33	251.73	0.960910	0.958365	0.953946	0.953176
AT17	**Albany Thicket**	**Albany Mesic Thicket**	59686.56	13235.13	58421.52	14500.17	57908.16	15013.53	57680.37	15241.32	0.818502	0.801154	0.794114	0.790991

Calculate geometric mean of proportion natural habitat remaining; per biome and overall

In [ ]:

```
#define custom function for geometric mean
def g_mean(x):
    a = np.log(x)
    return np.exp(a.mean())
```

In [ ]:

```
#calculate geometric mean
gmb = pt90to20[[1990,2014,2018,2020]].groupby("BIOME_18").apply(g_mean).reset_index()
gm_overall = pt90to20[[1990,2014,2018,2020]].apply(g_mean).reset_index()
gm_overall.columns =['YEAR', 'GMEAN_propnat']
#display overall summary EAI dataframe
gm_overall.head()
```

Out[ ]:

	YEAR	GMEAN_propnat
0	1990	0.750626
1	2014	0.718949
2	2018	0.703781
3	2020	0.696478

In [ ]:

```
#make biome level summary of Geometric mean "long" and reset index
gmb_long = gmb.melt(id_vars = "BIOME_18", var_name = "YEAR", value_vars=[1990,2014,2018,2020], value_name="GMEAN")
#display first few rows of summary per biome per year dataframe
gmb_long.head()
```

Out[ ]:

	BIOME_18	YEAR	GMEAN
0	Albany Thicket	1990	0.841783
1	Azonal Vegetation	1990	0.690857

	BIOME_18	YEAR	GMEAN
2	Desert	1990	0.824423
3	Forests	1990	0.859339
4	Fynbos	1990	0.661176

In [ ]:

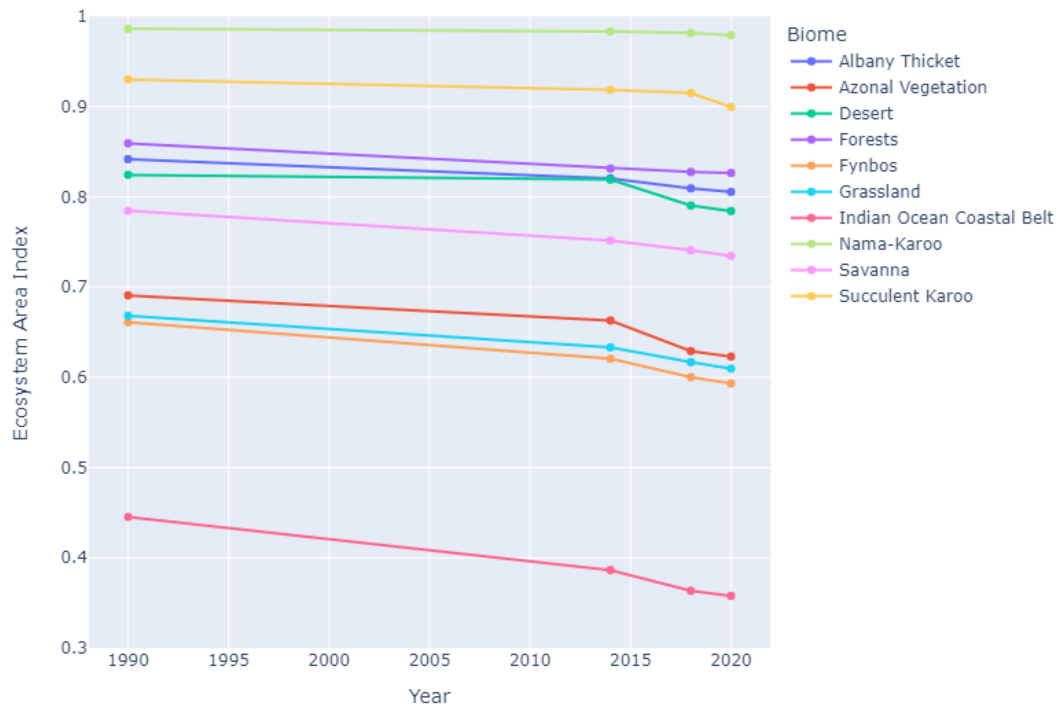
```
#export datafrmes to csv for use in other applications
pt90to20.to_csv('C:\\Users\\SkownoA\\OneDrive - sanbi.org.za\\GIS\\Monitoring\\EcosystemAreaIndex\\2020\\Computations\\EAI_data_pivoted_in_Pandas.csv')
gmb_long.to_csv('C:\\Users\\SkownoA\\OneDrive - sanbi.org.za\\GIS\\Monitoring\\EcosystemAreaIndex\\2020\\Computations\\gmb_long.csv')
gmb.to_csv('C:\\Users\\SkownoA\\OneDrive - sanbi.org.za\\GIS\\Monitoring\\EcosystemAreaIndex\\2020\\Computations\\gmb.csv')
gm_overall.to_csv('C:\\Users\\SkownoA\\OneDrive - sanbi.org.za\\GIS\\Monitoring\\EcosystemAreaIndex\\2020\\Computations\\gm_overall.csv')
```

Make line graphs of Ecosystem Area Index (overall and per Biome) over time

In [ ]:

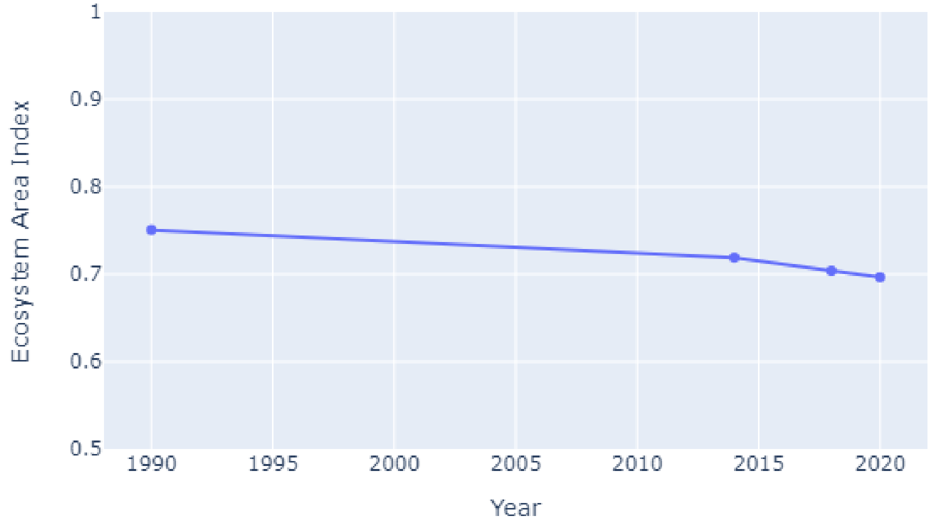
```
#using plotly express - make line plot per Biome of EAI 1990 - 2020
fig = px.line(gmb_long, x='YEAR', y='GMEAN', color='BIOME_18', markers=True, width=800, height=600,
labels={
    "YEAR":"Year",
    "GMEAN":"Ecosystem Area Index",
    "BIOME_18":"Biome"
}
)
fig.update_layout(yaxis_range=[0.3,1])
fig.show(renderer='notebook')
```

```
#last line ensures that the fig shows up in the html export of the notebook...using default fig(show) does not work
```



In [ ]:

```
#using plotly express - make line plot  of overall EAI 1990 - 2020
fig = px.line(gm_overall, x='YEAR', y='GMEAN_propnat', markers=True, width=650, height=400,
labels={
    "YEAR":"Year",
    "GMEAN_propnat":"Ecosystem Area Index"
    }
)
fig.update_layout(yaxis_range=[0.5,1])
fig.show(renderer='notebook')
```


Ecosystem Area Index
1
0.9
0.8
0.7
0.6
0.5
1990
1995
2000
2005
2010
2015
2020
Year