Modeling Sustainable Development in Hawaii

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Overview

- **Triple Bottom Line**
- **Economy, Environment, Society**
- **Hawaii as the "proving ground"**
- **Great data, models, tools, technologies**
- ***Mapping and modeling urban growth***
- **Socio-economic-environmental relationships**
- ***"Design of Density"* (dense cities)**
- **Concluding comments…**

Why Hawaii?

Availability of excellent data

Very Centralized System of Government

Most endangered species

Interesting mix of land uses

  dense urban areas

  rural areas

  conservation districts

Diverse environments: coastal, forest, mountain, perennial streams, natural lakes, reservoirs, upland bogs, coastal marshes, mangrove swamps, anchialine ponds…

Rich cultural history

Economic Tools

- **Input-output tables**
- **Model of state's economy**
- **Relationship between economic growth and impact on the environment**
- **Water use, wastewater, solid waste, energy, fossil fuel use**
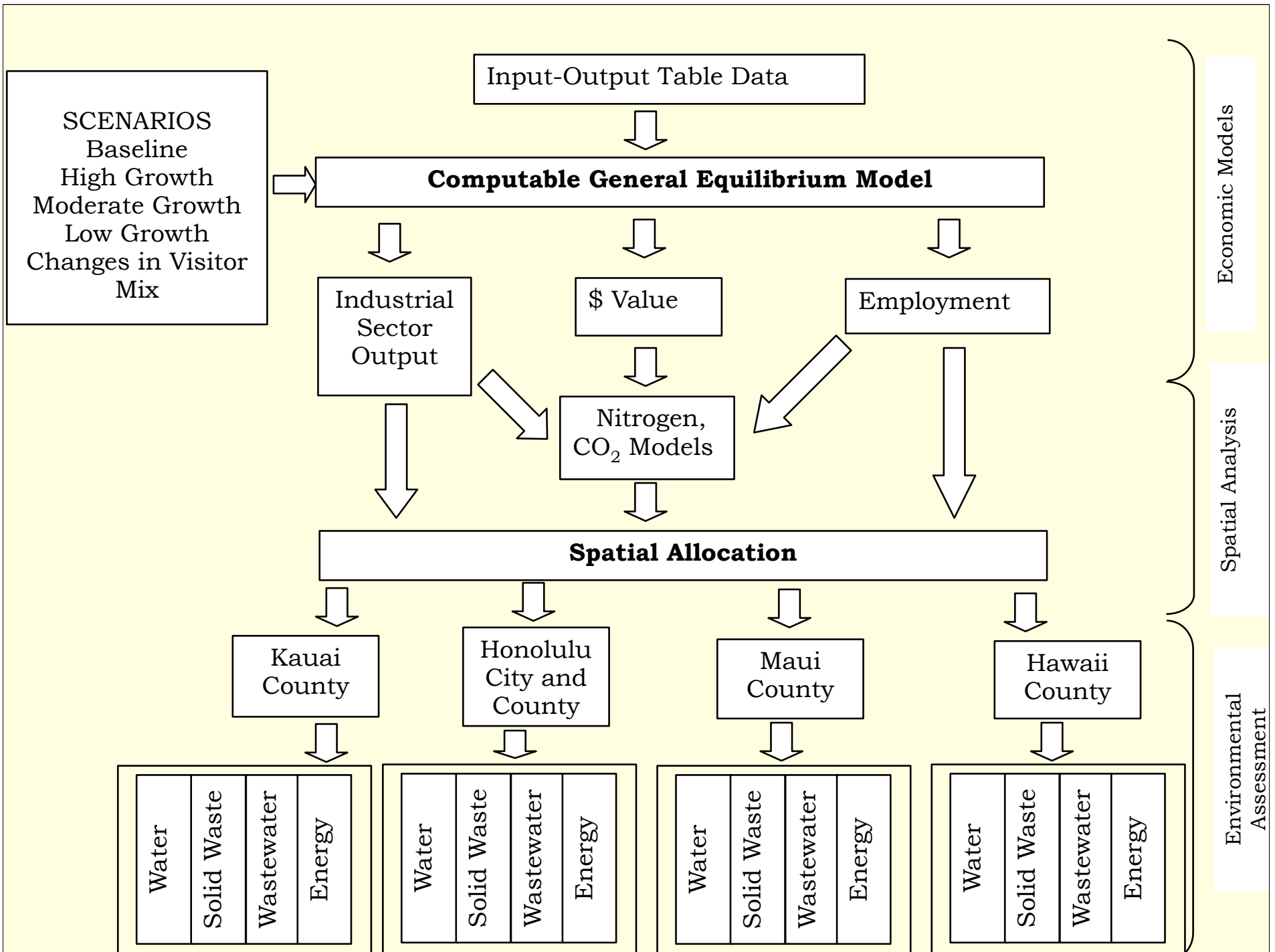- **Linked to GIS**

DATA SOURCES

Hawaii Input-Output Study: Benchmark Report

- **131 sectors**

- **Statewide report**

- **Output in $ by sector**

- **Intermediate demand**

- **Employment by sector**

- **Households, Visitors, Government, Military**

- **Appendix A. NAICS Codes for industries in Hawaii**

Figure 2.1 An Overview of an Input-Output Table

	INDUSTRIES 1,2,3,...,131	Final Demand Sectors	Total
I N D U S T R I E S 1, 2, 3, ... 131	**Block A** Inter-Industry Transactions	**Block B** Final demand (sales to households, visitors, government, investment, and exports)	Total industry output (sales)
Final pay-ments Sectors	**Block C** Primary payments (payments for labor, capital, land, loans, taxes, and imported goods)		Total pay-ments
Total	Total industry input (purchases)	Total expenditures	

Box / Node	Text

Economic Models

Input-Output Table Data

SCENARIOS
Baseline
High Growth
Moderate Growth
Low Growth
Changes in Visitor Mix

Computable General Equilibrium Model

Industrial Sector Output

$ Value

Employment

Spatial Analysis

Nitrogen, CO_2 Models

Spatial Allocation

Environmental Assessment

Kauai County

Honolulu City and County

Maui County

Hawaii County

Water | Solid Waste | Wastewater | Energy

Water | Solid Waste | Wastewater | Energy

Water | Solid Waste | Wastewater | Energy

Water | Solid Waste | Wastewater | Energy

Overview of Economy

Population (thousands)   1,211.6
Labor Force (thousands)   594.7
Job Count (full-time & part-time
 & self-employed) (thousands)   742.2
Visitor Expenditures ($ million)   **10,931.0**
Household Expenditures ($ million)   **24,962.0**
Wage & Salary Income ($ million)
          21,626.2
Proprietor's Income ($ million)   2,088.0
Gross State Product ($ million)   *38,537.0

*Does not include imports nor interindustry demand

Structure of Hawaii's Economy

Industry	Output ($m)	Output (%)
Agriculture	823	1.4%
Construction	3,524	6.0%
Manufacturing	3,416	5.8%
Air Transportation	2,044	3.5%
Transportation	1,465	2.5%
Entertainment	844	1.4%
Golf	230	0.4%
Accommodations	12,496	21.2%
Restaurants	2,275	3.9%
Trade	6,312	10.7%
Services	15,181	25.8%
Utilities	1,691	2.9%
Government	8,566	14.6%

I/O Methods

$$R_i = \sum_{k=1}^{n} r_{ik} + \sum_{y} r_{iy}$$

i = type of infrastructure
r_{ik} = direct infrastructure use type i by the kth industry sector
r_{iy} = direct infrastructure use type i by the final demand sector, y = residents, visitors, etc.
n = number of industry sectors

$$\rho_{ik} = \frac{r_{ik}}{x_k}$$

x_k = total output of industry sector k (**DIRECT REQUIREMENTS**)

$$t_{ij} = \rho_{ik} (I - A)^{-1}{}_{kj}$$

$(I-A)^{-1}{}_{kj}$ = total requirements matrix or Leontief inverse
(TOTAL REQUIREMENTS)

$$p_i = \rho_{ik} (I - A)^{-1}{}_{kj} \, y_j$$

y_j = PCEs or visitor expenditures in sector j
(INDIRECT REQUIREMENTS)

Water and Sewer Demand by Sector

Industry	Output ($million)	Household expenditures ($million)	Visitor's expenditures ($million)	Water (1000 gallons)	Sewer (1000 gallons)
Hotels	3,456.4	146.1	3,271.3	4,392,570	3,514,056
Real estate rental	9,039.8	5,278.1	620.9	4,220,882	3,376,705
Restaurants	2,274.7	1,017.1	1,126.2	3,102,155	2,481,724
Wholesale trade	1,939.0	687.9	210.0	517,582	414,066
Retail trade	4,372.8	2,290.2	1,254.8	-	-
Performing arts	155.6	62.2	31.1	206,573	165,258
Amusement	157.1	27.6	129.5	68,670	54,936
Recreation	150.7	63.7	84.7	155,794	124,635
Museums historical	77.2	38.5	38.6	83,844	67,075
Sightseeing transport	303.7	15.2	285.5	-	-
Golf courses	229.8	88.5	141.3	1,138,964	911,171
Air transportation	2,044.1	337.5	1,555.6	229,530	183,624
Trucking	279.0	99.8	20.1	86,716	69,373
Water transportation	522.8	133.9	123.2	44,838	35,870
Ground transportation	128.9	34.6	76.2	110,274	88,219
Automobile rental	393.3	32.5	314.8	571,348	457,078
Parking lots	109.4	77.2	10.4	149,095	119,276

Infrastructure Services Demand

	Water (1000 gal)	Sewer (1000 gal)	Electricity (GWh)	Propane (mmBtu)	Solid Waste (1m lbs)
Direct Use Residents	43,299,259	22,953,795	2,665	559,900	1,709.9
Indirect Use Residents	17,986,206	15,489,178	2,542	715,179	707.9
Indirect Use Visitors	12,237,755	10,195,386	2,013	1,536,101	436.8
Total Use by Residents	**61,285,465**	**38,442,973**	**5,207**	**1,275,079**	**2,417.9**
Total Use by Visitors	**12,237,755**	**10,195,386**	**2,013**	**1,536,101**	**436.8**

Infrastructure Services Demand, Per Day

	Water (gallons)	Sewer (gallons)	Electricity (KWh)	Propane (mmBtu)	Solid Waste (lbs)
Direct Use per Resident	97.9	51.9	6.0	0.001	3.9
Direct Use per Visitor	-	-	-	-	-
Indirect Use per Resident	40.7	35.0	5.7	0.002	1.6
Indirect Use per Visitor	213.3	177.7	35.1	0.027	7.6
Total Use per Resident	**138.6**	**86.9**	**11.8**	**0.003**	**5.5**
Total Use per Visitor	**213.3**	**177.7**	**35.1**	**0.027**	**7.6**

Spatial Analytic Tools

- USGS
- Census
  - Population
  - Housing
  - Employment
- Land Use files
- Environment

PARTS OF A GIS
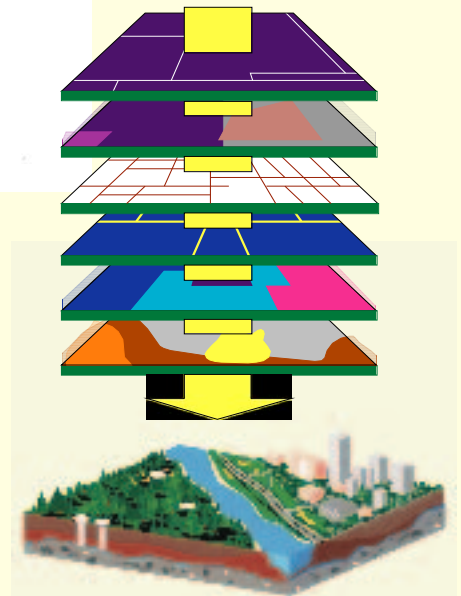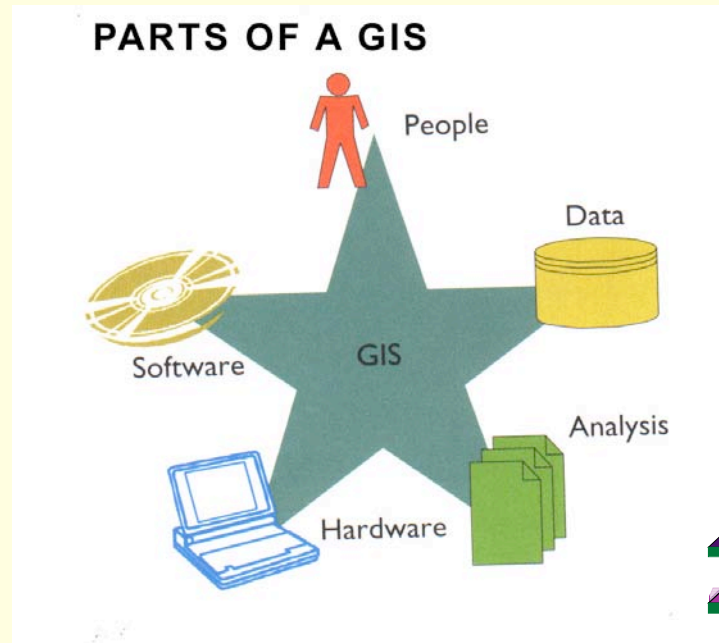
Land Use Classification
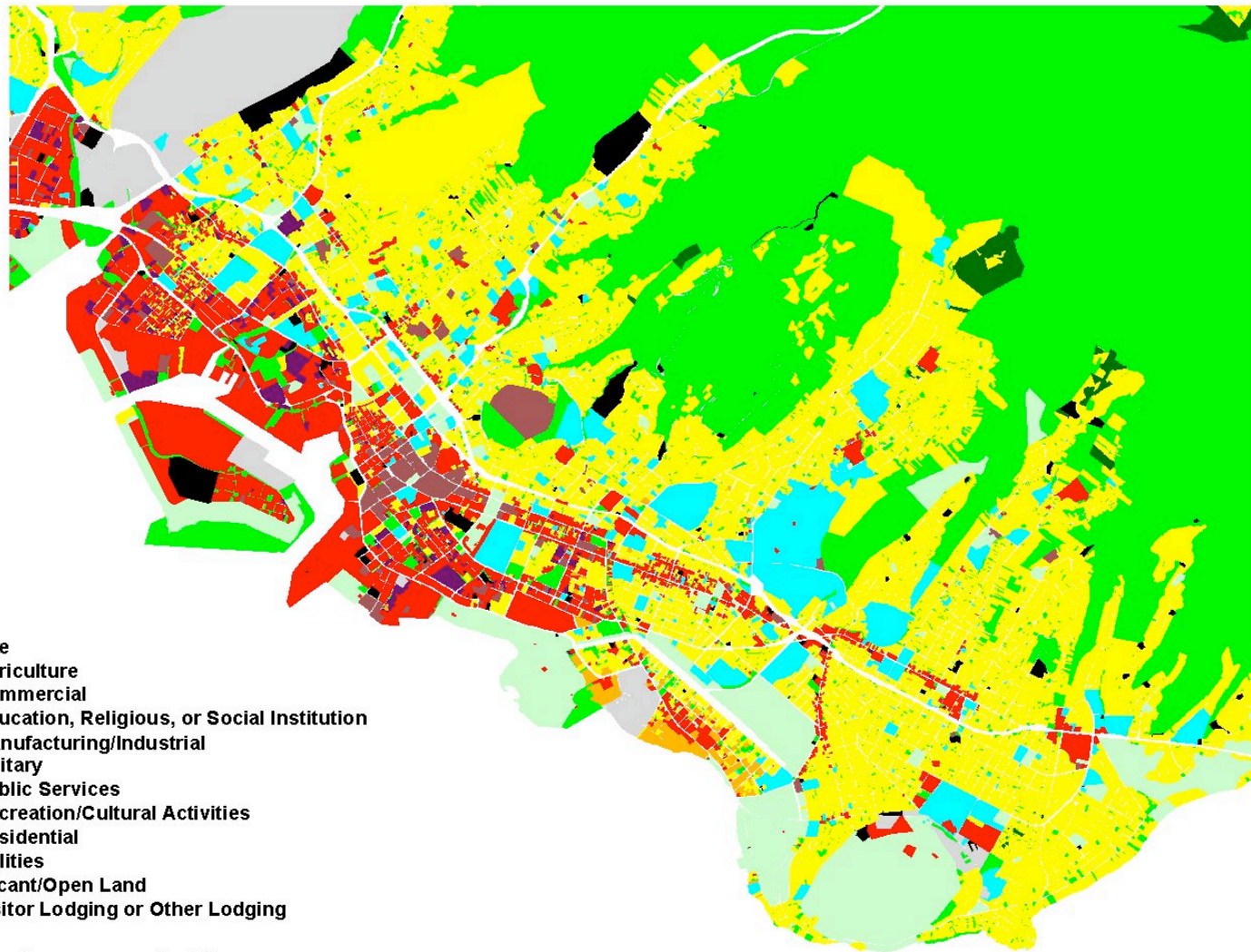
Land Use
- ■ Agriculture
- ■ Commercial
- ■ Education, Religious, or Social Institution
- ■ Manufacturing/Industrial
- ■ Military
- ■ Public Services
- ■ Recreation/Cultural Activities
- ■ Residential
- ■ Utilities
- ■ Vacant/Open Land
- ■ Visitor Lodging or Other Lodging

0   1   2 Miles

N

Waikiki Area

96815
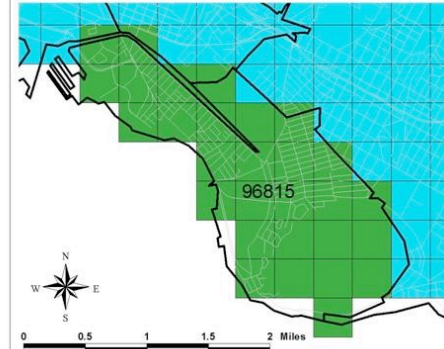
ZipCode Boundary
Street
Waikiki Area

N
W E
S

0   0.5   1   1.5   2 Miles

TMK Parcels
Land Use Activity

Unknown
Household Dwelling
Visitor Lodging
Boarding
Large Scale Repair - Ship Building
Air Transport
Food and Liquor
General Merchandise
Apparel
Eating and Drinking
Motor Vehicle
Financial
Personal Services
Business Services
Automotive Services
Entertainment

Commercial Recreation
Membership Recreation
Public Recreation
Nature Exhibition
Public Administration
Military
Public Order
Educational Services
Religious
Social Services
Other Services
Communication
Electricity
Subdivided Vacant
Unsubdivided Vacant
Remnant
Restricted
Right of Way
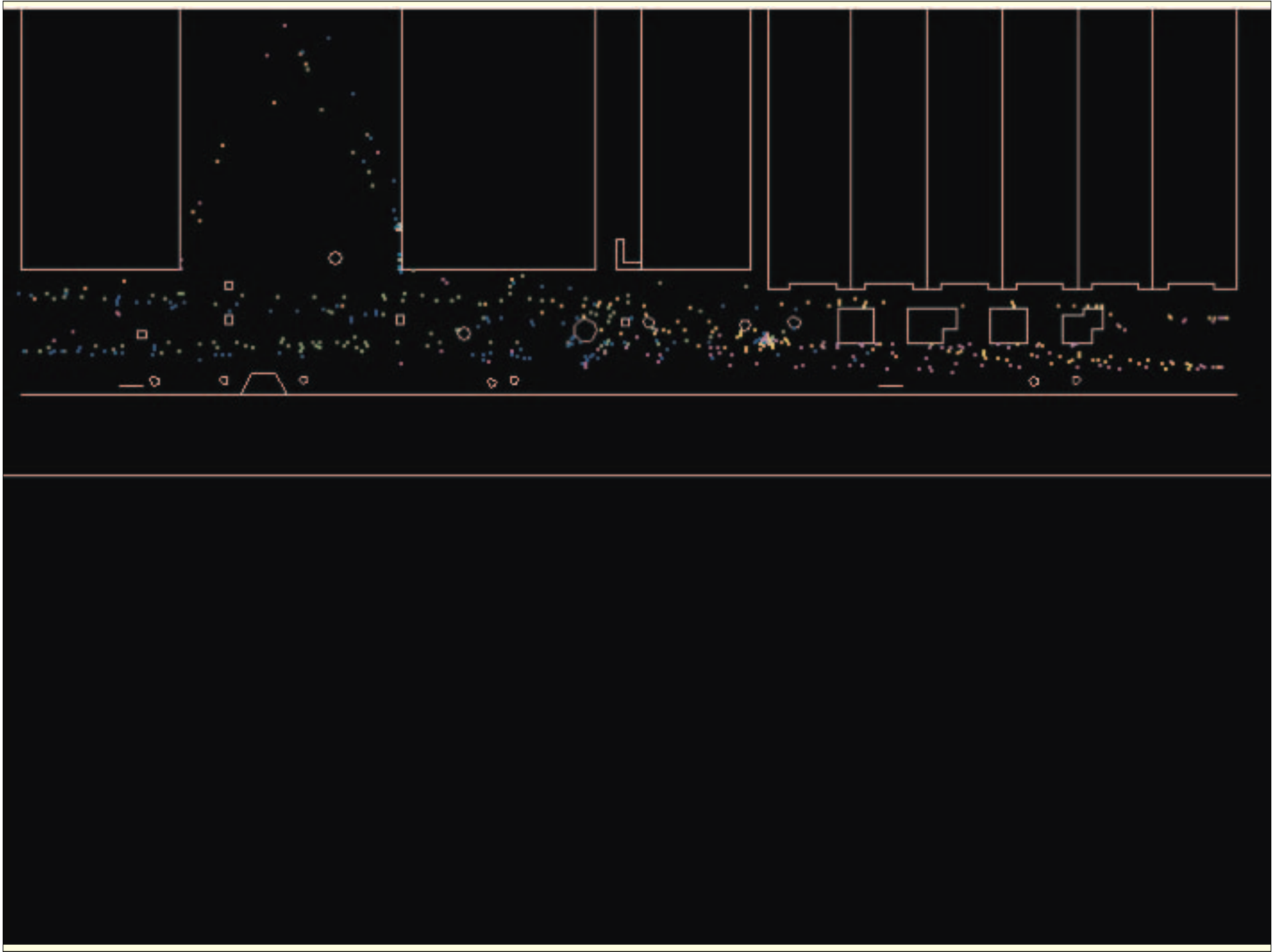
Population Distribution by Zip Code in 1999

Land Use by
0.1-mile Grid Structure

Land Use Classification

Agricultural
Conservation
Urban

N
W E
S

0   5   10   Miles
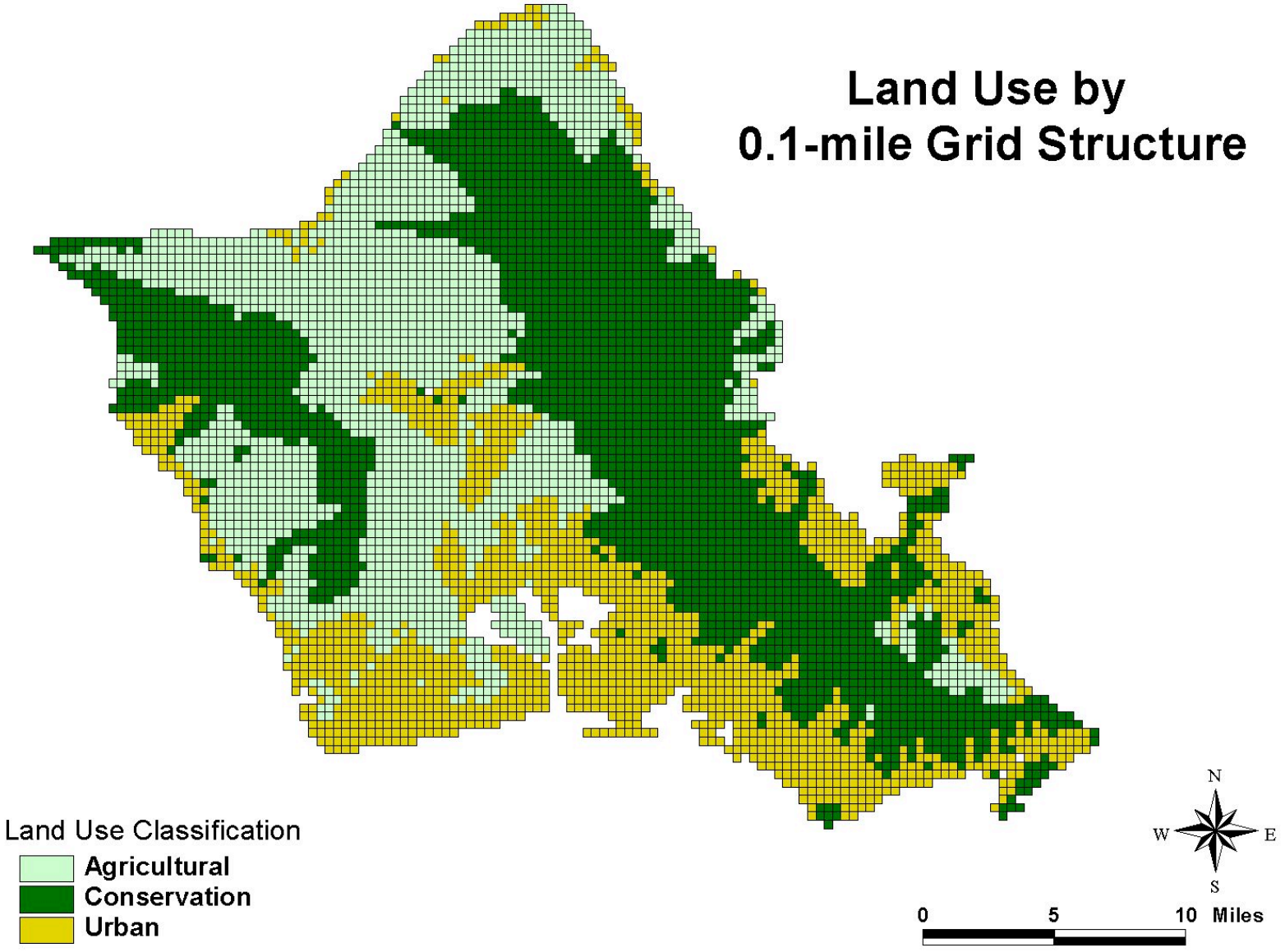
Population Distribution in Oahu by 0.1-sqmile Grid Structure

Number of Population

- 0
- 0 - 546
- 546 - 931
- 931 - 1428
- 1428 - 2614
- 2614 - 3918

N
W E
S

0   5   10 Miles
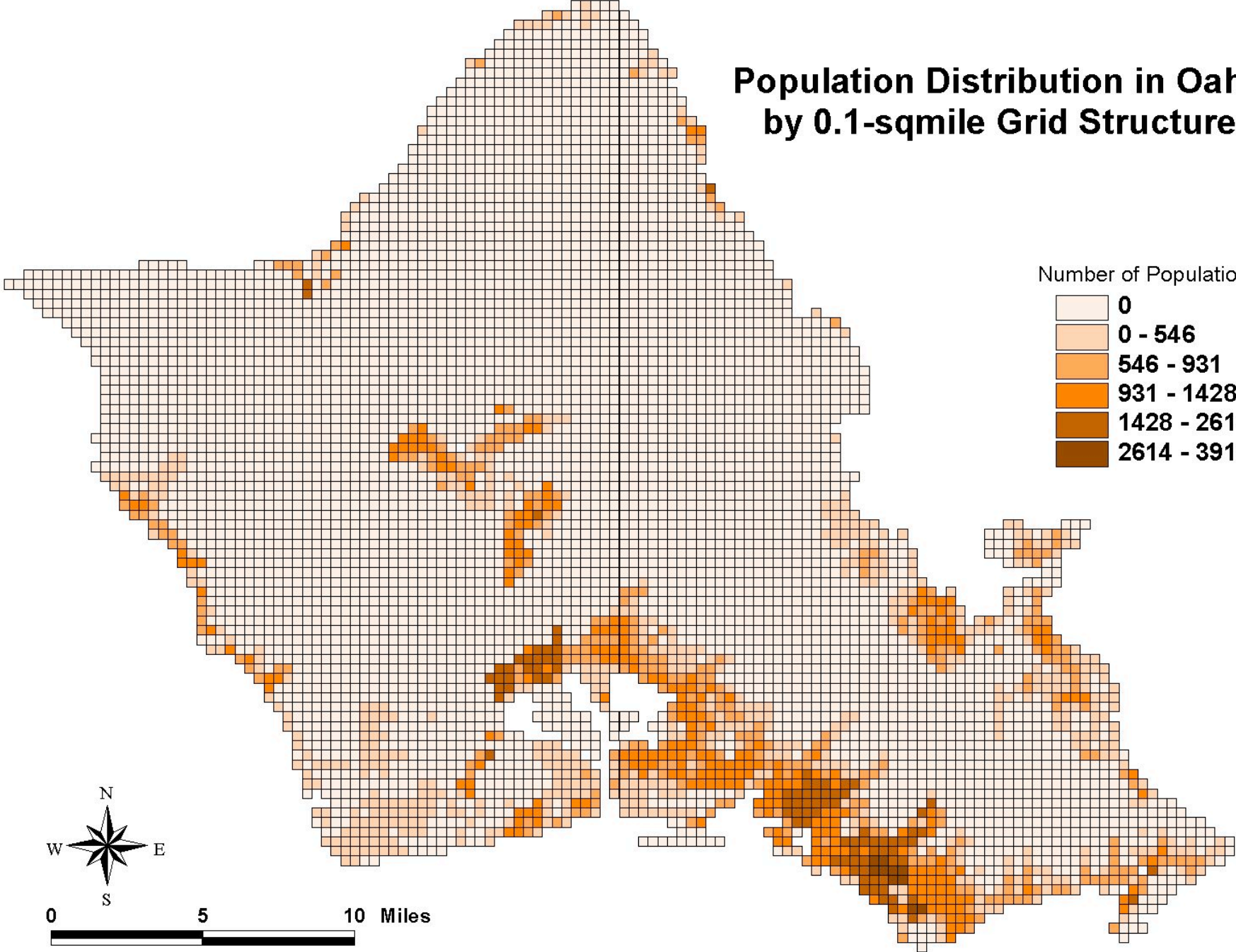
Economic Output Total
by 0.1-mile Grid Structure

Million Dollars

- 0
- 0 - 11.93
- 11.93 - 35.06
- 35.06 - 88.98
- 88.98 - 178.7
- 178.7 - 333.3

0   5   10 Miles
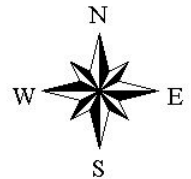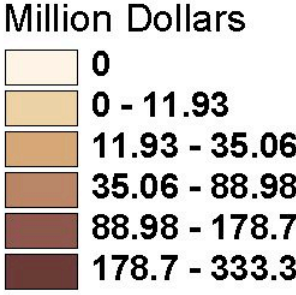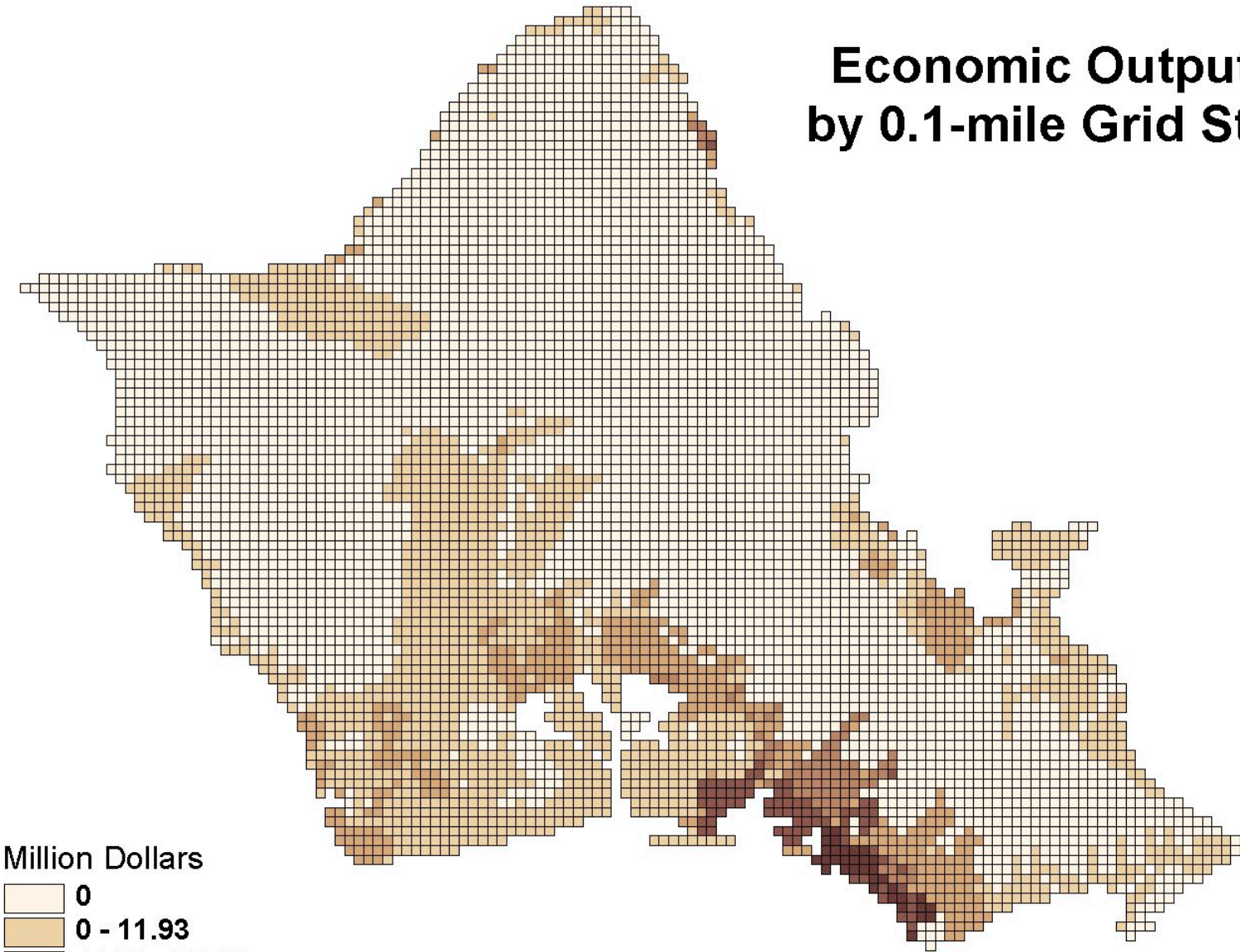
Baseline Water Consumption on Oahu by Industries, Visitors, and Residents

in gallons/year
- 0
- 0 - 56110155.01
- 56110155.01 - 121247993.14
- 121247993.14 - 208191041.96
- 208191041.96 - 379187373.11
- 379187373.11 - 1304904268.4
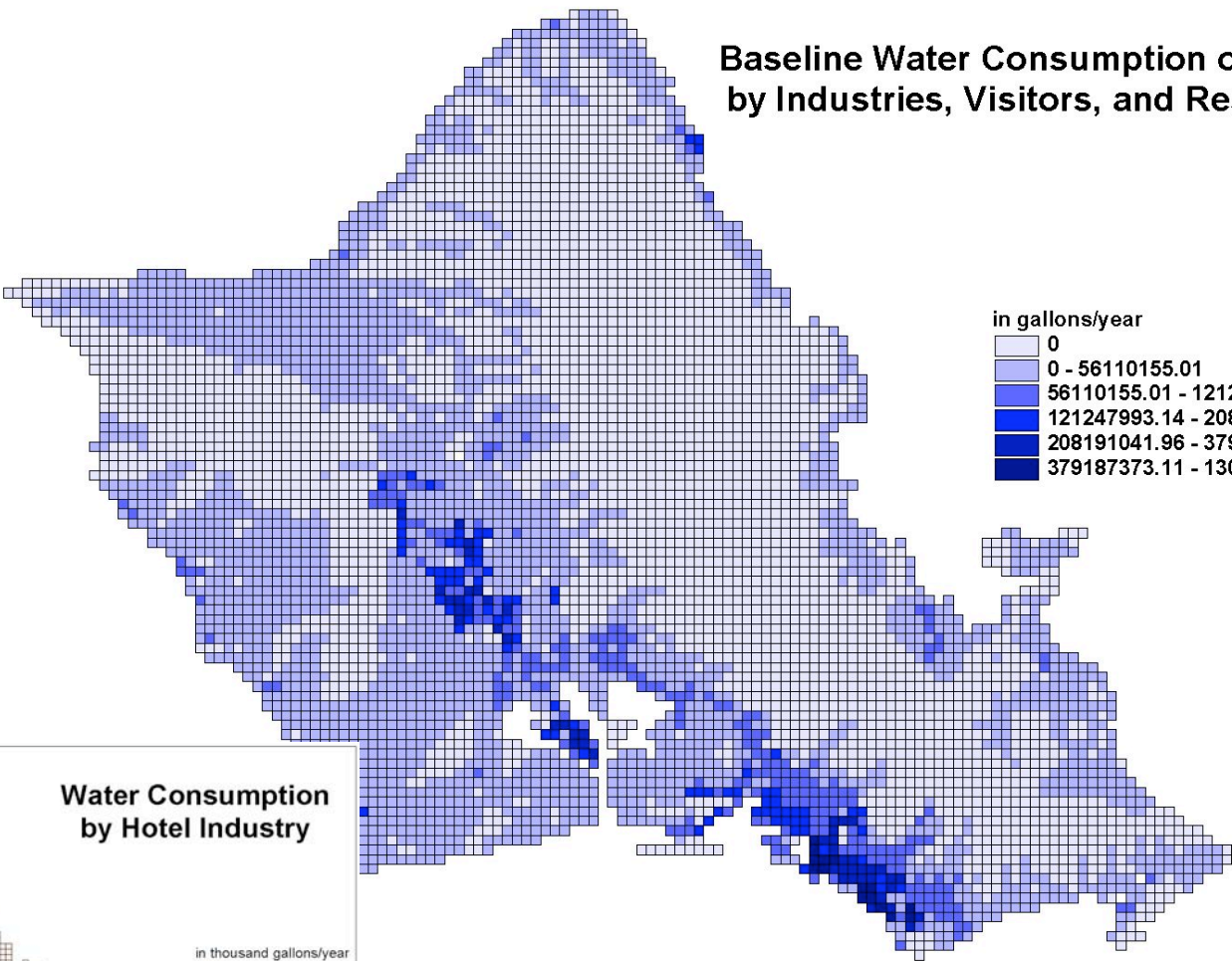
Miles

Water Consumption by Hotel Industry

in thousand gallons/year
- 0
- 0 - 23075
- 23075 - 60749
- 60749 - 154395
- 154395 - 252491
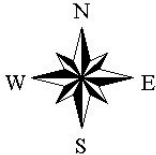- 252491 - 425681

N
W   E
S
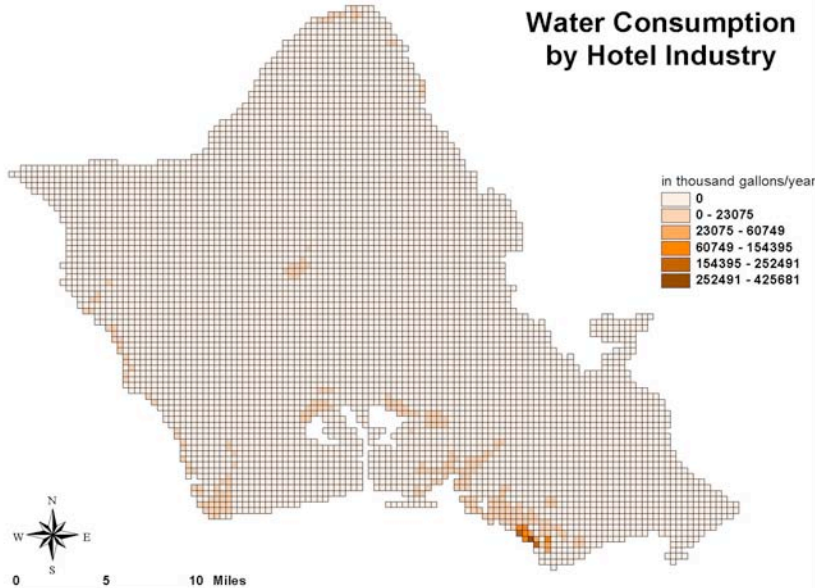
0   5   10   Miles

Baseline Solid Waste Generation
on Oahu
by Industries, Visitors, and Residents
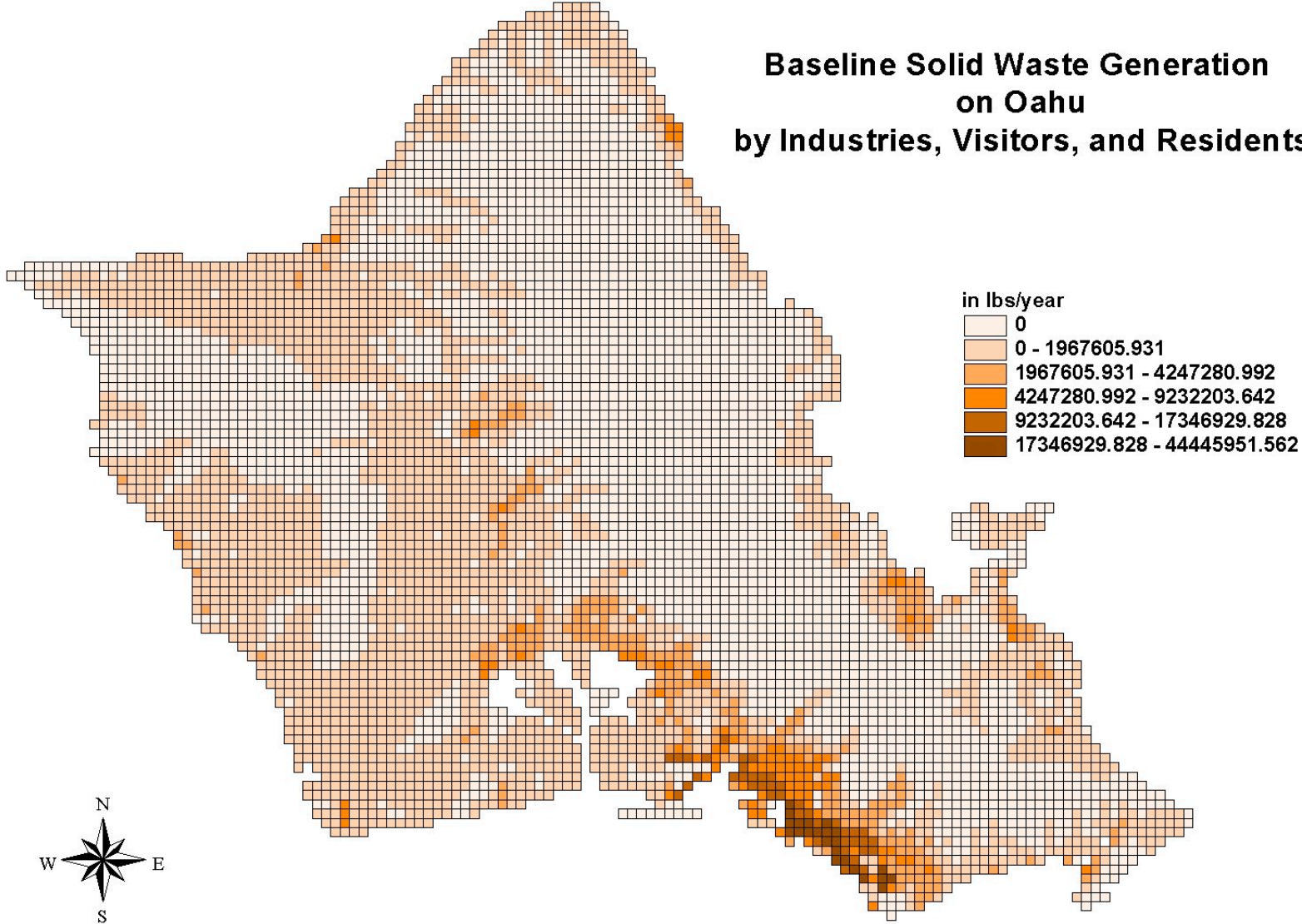
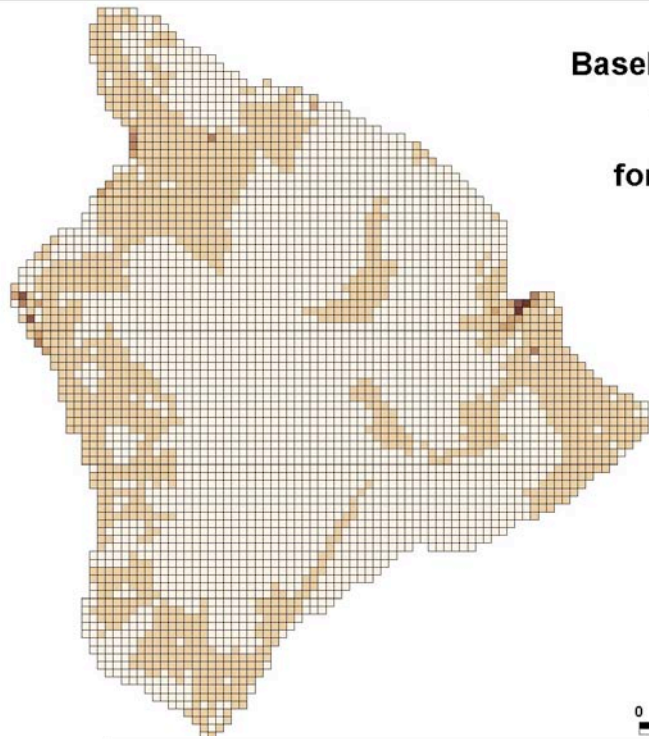in lbs/year
0
0 - 1967605.931
1967605.931 - 4247280.992
4247280.992 - 9232203.642
9232203.642 - 17346929.828
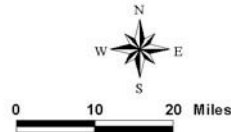17346929.828 - 44445951.562

N
W E
S

0   5   10 Miles

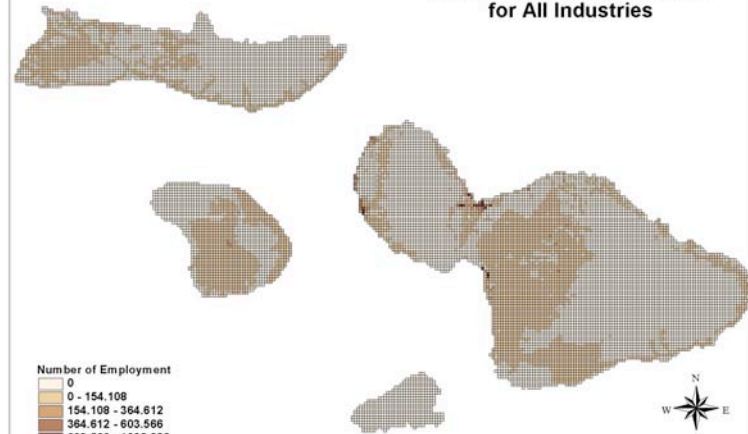**Baseline Employment Distribution on Hawaii for All Industries**

Number of Employment
- 0
- 0 - 301.761
- 301.761 - 642.526
- 642.526 - 1225.896
- 1225.896 - 2021.675
- 2021.675 - 4321.123

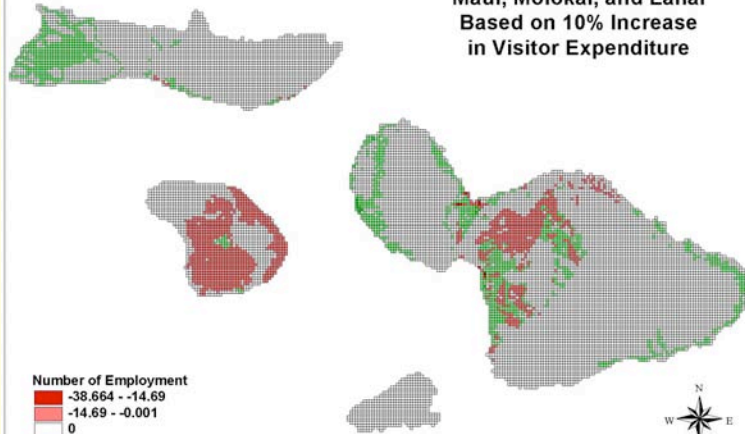**Baseline Employment Distribution on Maui, Molokai, and Lanai for All Industries**

Number of Employment
- 0
- 0 - 154.108
- 154.108 - 364.612
- 364.612 - 603.566
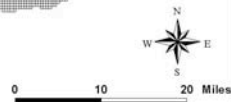- 603.566 - 1092.888
- 1092.888 - 2035.397

Employment Change on Maui, Molokai, and Lanai Based on 10% Increase in Visitor Expenditure
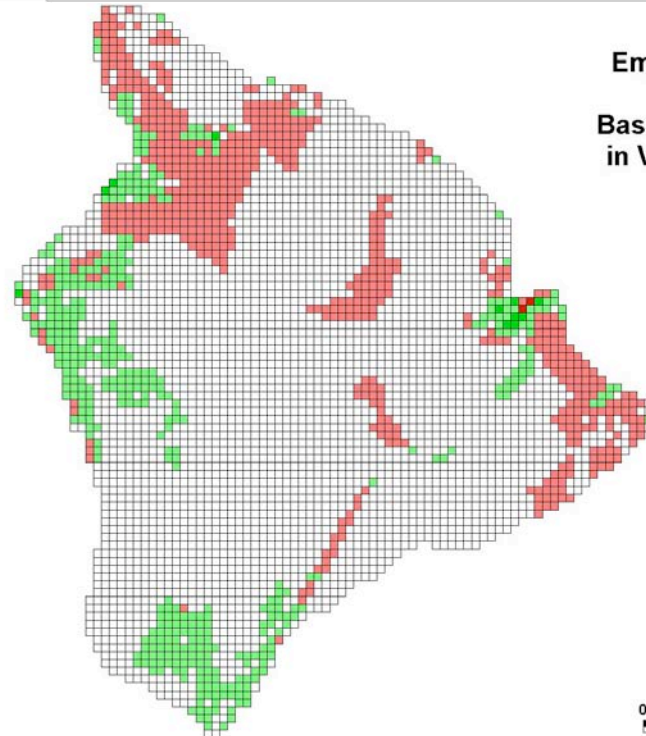
Number of Employment
- -38.664 - -14.69
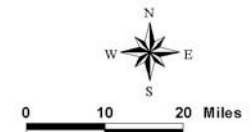- -14.69 - -0.001
- 0
- 0.001 - 4.631
- 4.631 - 13.497

Employment Change on Hawaii Based on 10% Increase in Visitor Expenditure

Number of Employment
- -79.284 - -60.242
- -60.242 - -0.001
- 0
- 0 - 5.646
- 5.646 - 12.61

Resident's and Visitor's Expenditures, 1997

Industry	Resident's expenditures ($million)	Visitor's expenditures ($million)	Percent distribution of resident's expenditures	Percent distribution of visitor's expenditures	Resident's expenditures per resident day ($)	Visitor's expenditures per visitor day ($)
Hotels	146.1	3,271.3	0.7%	32.6%	0.3	57.0
Air transportation	337.5	1,555.6	1.7%	15.5%	0.8	27.1
Retail trade	2,292.0	1,254.8	11.3%	12.5%	5.2	21.9
Restaurants	1,036.5	1,126.2	5.1%	11.2%	2.3	19.6
Real estate rental	5,278.1	620.9	26.1%	6.2%	11.9	10.8
Automobile rental	32.5	314.8	0.2%	3.1%	0.1	5.5
Sightseeing transport	15.2	285.5	0.1%	2.8%	0.0	5.0
Wholesale trade	687.9	210.0	3.4%	2.1%	1.6	3.7
Travel reservations	58.9	191.2	0.3%	1.9%	0.1	3.3
Golf courses	108.4	141.3	0.5%	1.4%	0.2	2.5
Education private	431.7	140.7	2.1%	1.4%	1.0	2.5
Amusement	47.1	129.5	0.2%	1.3%	0.1	2.3
Water transportation	133.9	123.2	0.7%	1.2%	0.3	2.1
Recreation	67.7	84.7	0.3%	0.8%	0.2	1.5
Health services	3,780.5	83.3	18.7%	0.8%	8.5	1.5
Ground transportation	34.6	76.2	0.2%	0.8%	0.1	1.3
Finance business professional	2,059.7	72.3	10.2%	0.7%	4.7	1.3
Food processing	419.5	52.3	2.1%	0.5%	0.9	0.9
Other government	264.9	45.6	1.3%	0.5%	0.6	0.8
Other services	848.7	39.9	4.2%	0.4%	1.9	0.7
Museums historical	42.5	38.6	0.2%	0.4%	0.1	0.7
Information	778.9	33.4	3.9%	0.3%	1.8	0.6
Performing arts	62.2	31.1	0.3%	0.3%	0.1	0.5
Trucking	99.8	20.1	0.5%	0.2%	0.2	0.4
Clothing manufacturing	39.8	18.8	0.2%	0.2%	0.1	0.3
Other manufacturing	35.9	16.6	0.2%	0.2%	0.1	0.3
Crops	56.6	15.8	0.3%	0.2%	0.1	0.3
Petroleum manufacturing	190.6	13.6	0.9%	0.1%	0.4	0.2
Laundry	60.0	12.7	0.3%	0.1%	0.1	0.2
Parking lots	77.2	10.4	0.4%	0.1%	0.2	0.2
Commercial fishing	24.0	1.4	0.1%	0.0%	0.1	0.0
Animal	50.8	1.3	0.3%	0.0%	0.1	0.0
Transit	30.9	0.4	0.2%	0.0%	0.1	0.0
Electricity	394.6	-	2.0%	0.0%	0.9	-
Water sewer	182.2	-	0.9%	0.0%	0.4	-
Natural gas	12.8	-	0.1%	0.0%	0.0	-
Waste management private	5.7	-	0.0%	0.0%	0.0	-
Landscaping services	-	-	0.0%	0.0%	-	-
Construction and mining	-	-	0.0%	0.0%	-	-
Chemical manufacturing	-	-	0.0%	0.0%	-	-
Total	20,225.9	10,033.5	100.0%	100.0%	45.7	174.9

Resident's and Visitor's Expenditures, 1997

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Hotels	146.1	3,271.3	0.7%	32.6%	0.3	57.0
Air transportation	337.5	1,555.6	1.7%	15.5%	0.8	27.1
Retail trade	2,290.0			12.5%	5.2	21.9
Restaurants	1,030.5	1,126.2	5.1%	11.2%	2.3	19.6
Real estate rental	5,278.1	620.9	26.1%	6.2%	11.9	10.8
Automobile rental	32.5	314.8	0.2%	3.1%	0.1	5.5
Sightseeing transport	15.2	285.5	0.1%	2.8%	0.0	5.0
	697.0	210				
Travel reservations	58.9	191.2	0.3%	1.9%	0.1	3.3
Golf courses	108.4	141.3	0.5%	1.4%	0.2	2.5
Education private	431.7	140.7	2.1%	1.4%	1.0	2.5
Amusement						
Water transportation	133.9	123.2	0.7%	1.2%	0.3	2.1
Museum		84.7	0.3%	0.8%	0.2	1.5
Health services	3,780.5	83.3	18.7%	0.8%	8.5	1.5
Industrial equipment						
Finance business professional	2,059.7	72.3	10.2%	0.7%	4.7	1.3
Food processing		55				0.9
Other government	264.9	45.6	1.3%	0.5%	0.6	0.8
	848.7	39.9	4.2%	0.4%	1.9	0.7
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Performing arts	62.2	31.1	0.3%	0.3%	0.1	0.5
Trucking	90.9	20	0.5%	0.2%		0.4
Clothing manufacturing	39.8	18.8	0.2%	0.2%	0.1	0.3
Other manufacturing	36.0	16.6	0.2%	0.2%	0.1	0.3
Crops	56.6	15.8	0.3%	0.2%	0.1	0.3
Petroleum manufacturing	90.6	13.6	0.9%	0.1%	0.4	0.2
Laundry	60.0	12.7	0.3%	0.1%	0.1	0.2
Railroads	77.2	10.4	0.4%	0.1%	0.2	0.2
Commercial fishing	24.0	1.4	0.1%	0.0%	0.1	0.0
Animal	50.8	1.2	0.3%	0.0%	0.1	0.0
Transit	30.9	0.4	0.2%	0.0%	0.1	0.0
Electricity	394.0	-	1.9%	0.0%	0.9	-
Water sewer	182.2	-		0.0%	0.4	-
Natural gas	12.8	-	0.1%	0.0%	0.0	-
Waste management private	5.7	-	0.0%	0.0%	0.0	-
Landscaping services	-	-	0.0%	0.0%	-	-
Construction and mining	-	-	0.0%	0.0%	-	-
Chemical manufacturing	-	-	0.0%	0.0%	-	-
Total	20,225.9	10,033.5	100.0%	100.0%	45.7	174.9

Visitors spend more than $10 billion annually
About $175 per day
Biggest expenditures on hotels, transport, restaurant meals…

Existing Labor can support 1.6% increase in real visitor expenditures
(7% nominal, inflation of 5.2%)
No growth in labor force transfers income from visitors to residents
1% increase in spending increases household spending by 1.1% in nominal terms

Increase in visitor spending produces increases demand for labor
Not all industries affected equally
Tourism and services are labor intensive
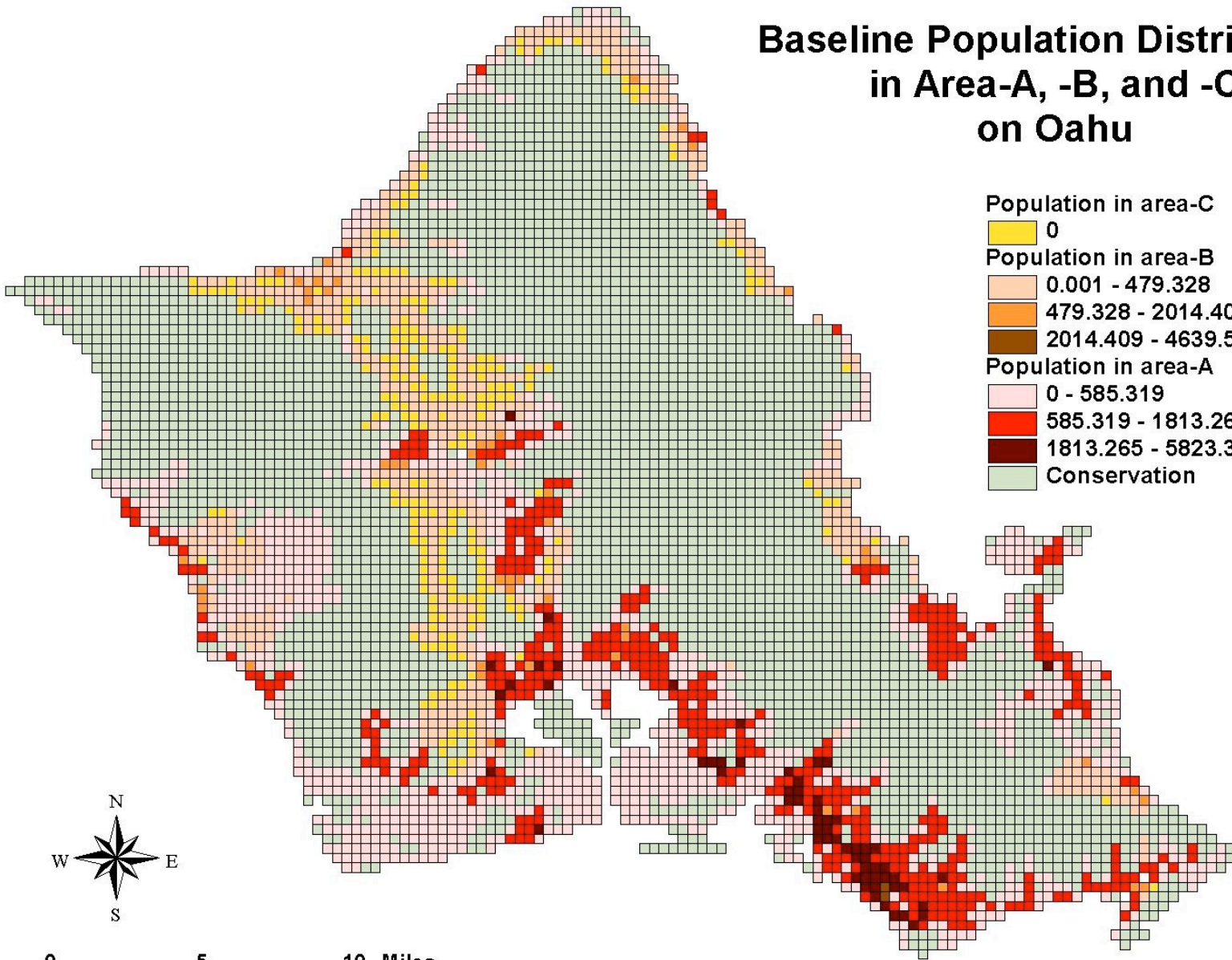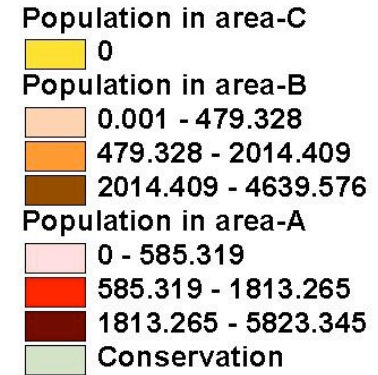Wages increase up to a point
Pressure for in-migration also increases
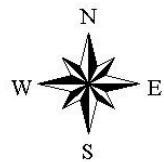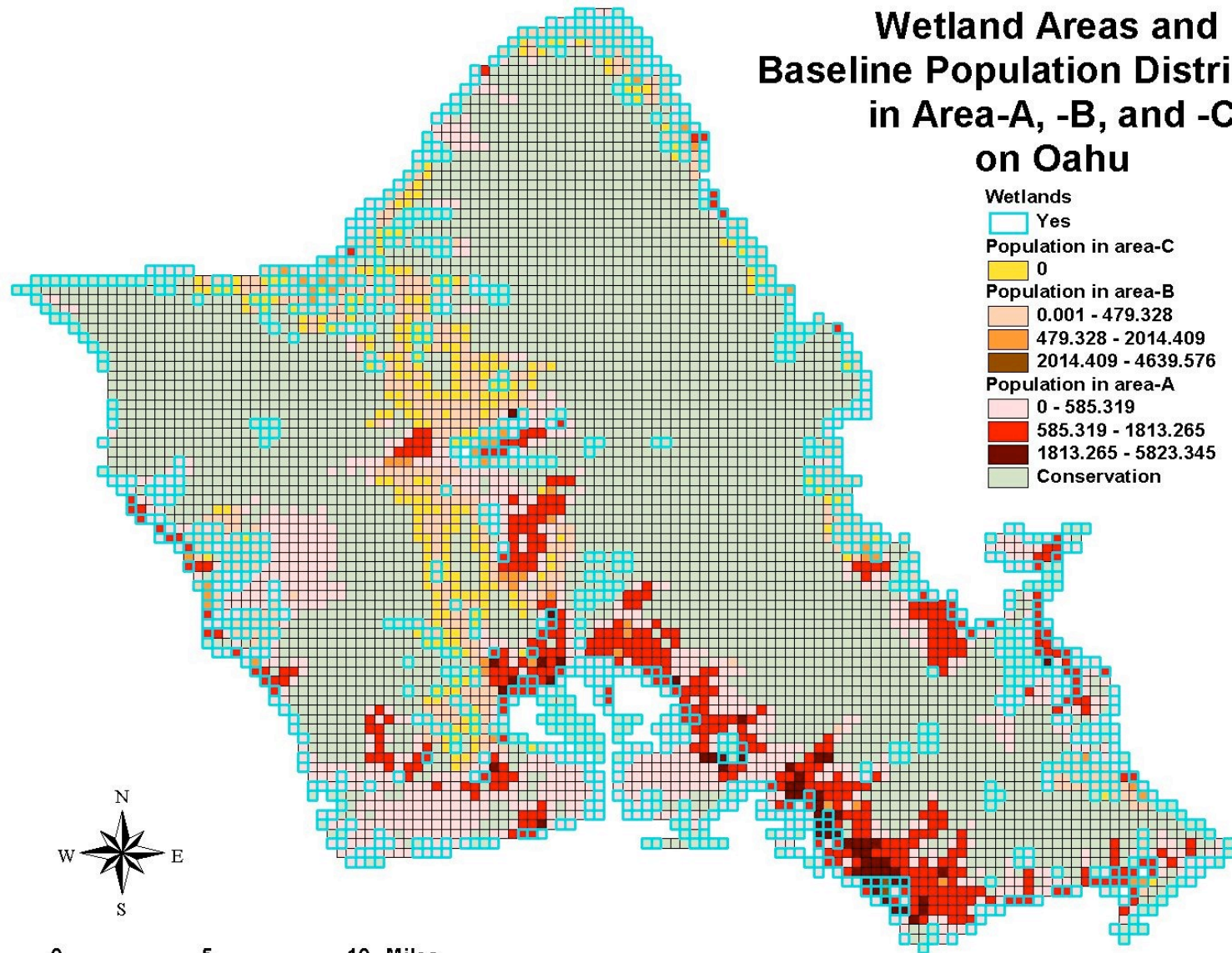Urbanization-Subdivision development-Sprawl

Urban Growth Model

- **Three classes of land (urbanized, partially developed, agricultural)**
- **High v. Low population growth rates**
- **Include or Exclude wetlands areas and natural areas for development**
- **Simulate development patterns over 30 year time period**
- **Mathematical model linked to GIS**

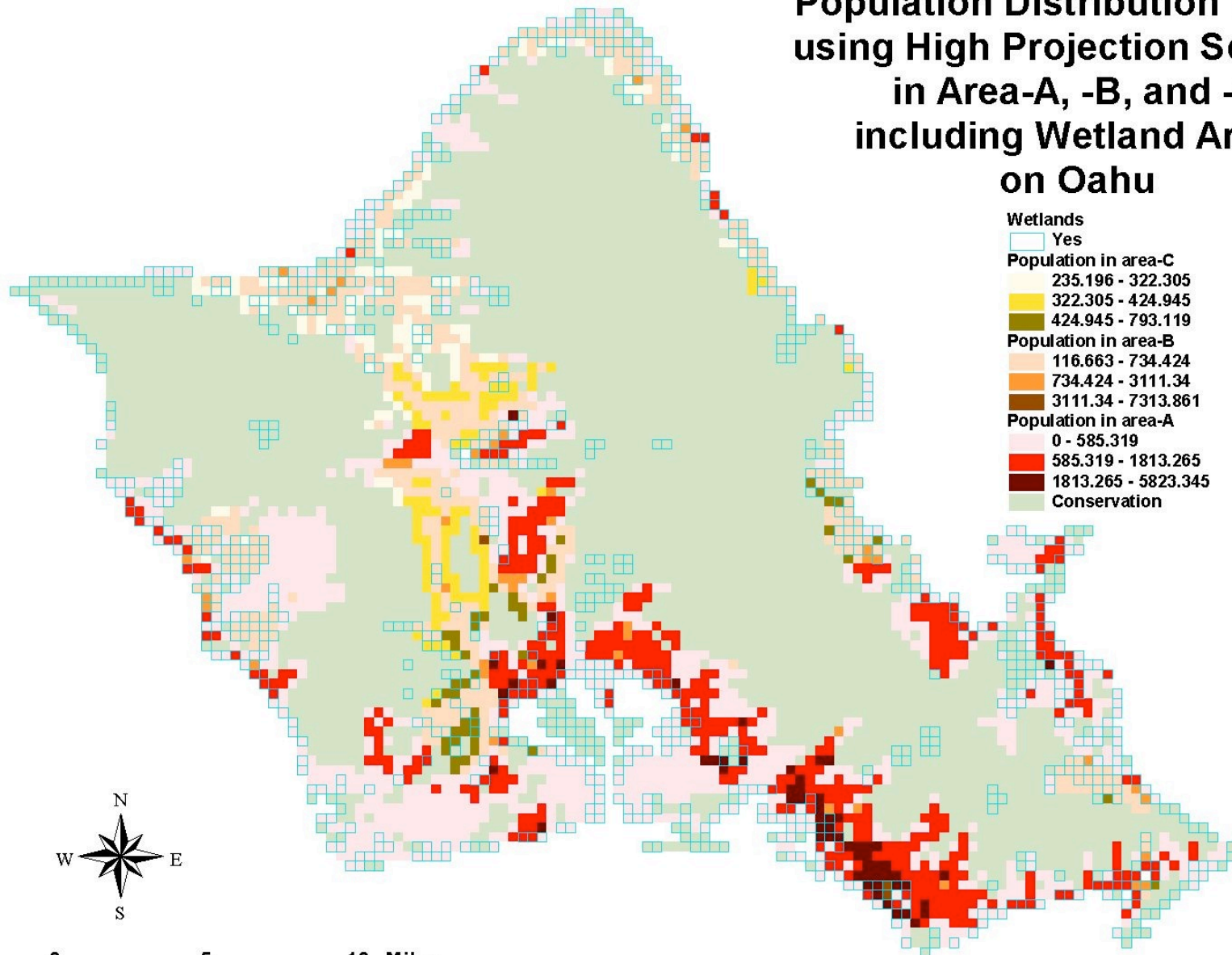Baseline Population Distribution in Area-A, -B, and -C on Oahu

Population in area-C
■ 0 (yellow)

Population in area-B
■ 0.001 - 479.328
■ 479.328 - 2014.409
■ 2014.409 - 4639.576

Population in area-A
■ 0 - 585.319
■ 585.319 - 1813.265
■ 1813.265 - 5823.345
■ Conservation

0   5   10   Miles

Wetland Areas and
Baseline Population Distribution
in Area-A, -B, and -C
on Oahu

Wetlands
Yes

Population in area-C
0

Population in area-B
0.001 - 479.328
479.328 - 2014.409
2014.409 - 4639.576

Population in area-A
0 - 585.319
585.319 - 1813.265
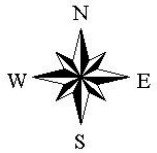1813.265 - 5823.345
Conservation

N
W   E
S
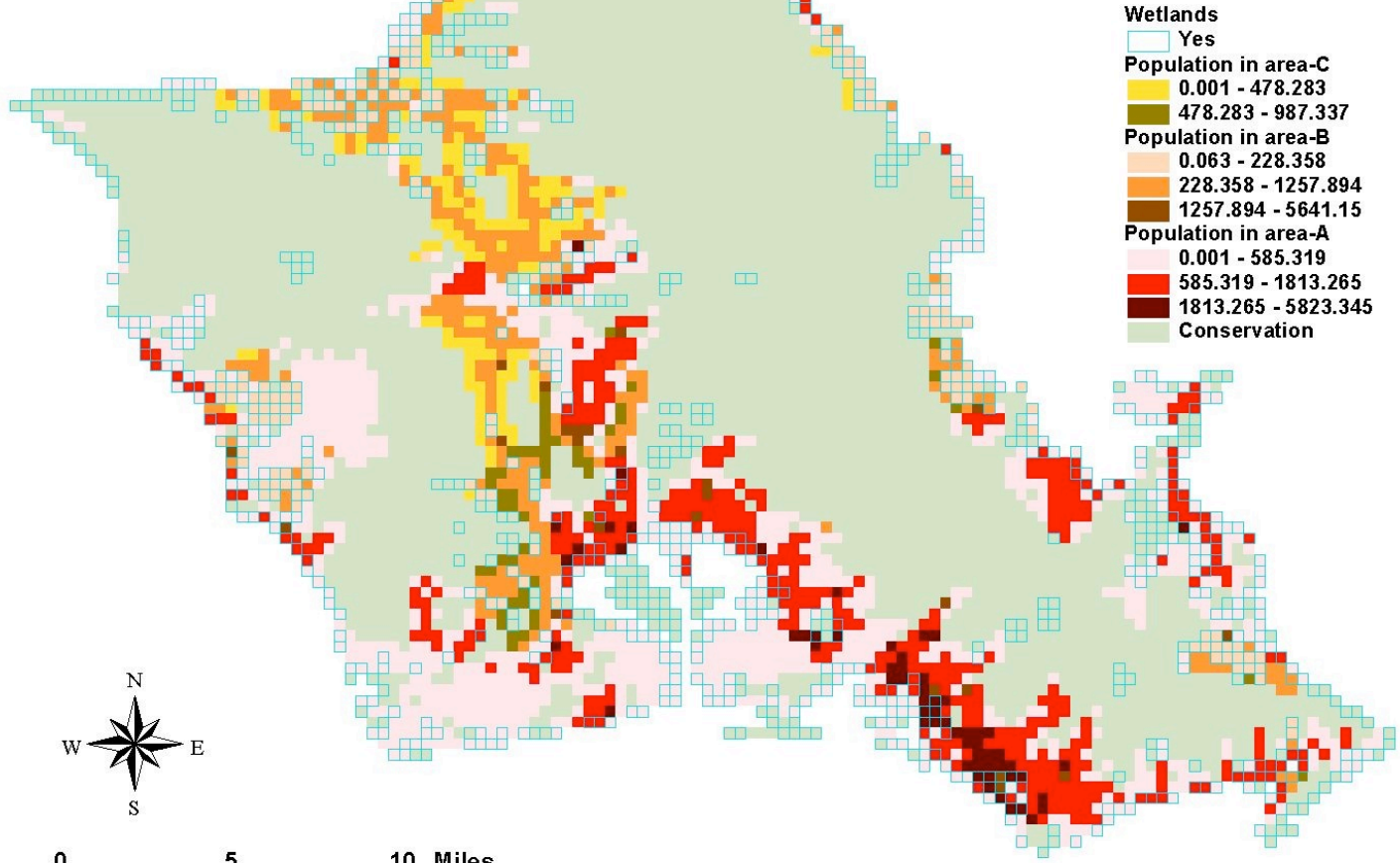
0   5   10 Miles

Population Distribution in 2030 using High Projection Scenario in Area-A, -B, and -C including Wetland Areas on Oahu

Wetlands
☐ Yes

Population in area-C
235.196 - 322.305
322.305 - 424.945
424.945 - 793.119

Population in area-B
116.663 - 734.424
734.424 - 3111.34
3111.34 - 7313.861

Population in area-A
0 - 585.319
585.319 - 1813.265
1813.265 - 5823.345
Conservation

N
W — E
S

0   5   10 Miles

Annual growth in area-A = 0%, B = 3%

Population Distribution in 2030 using High Projection Scenario in Area-A, -B, and -C excluding Wetland Areas on Oahu
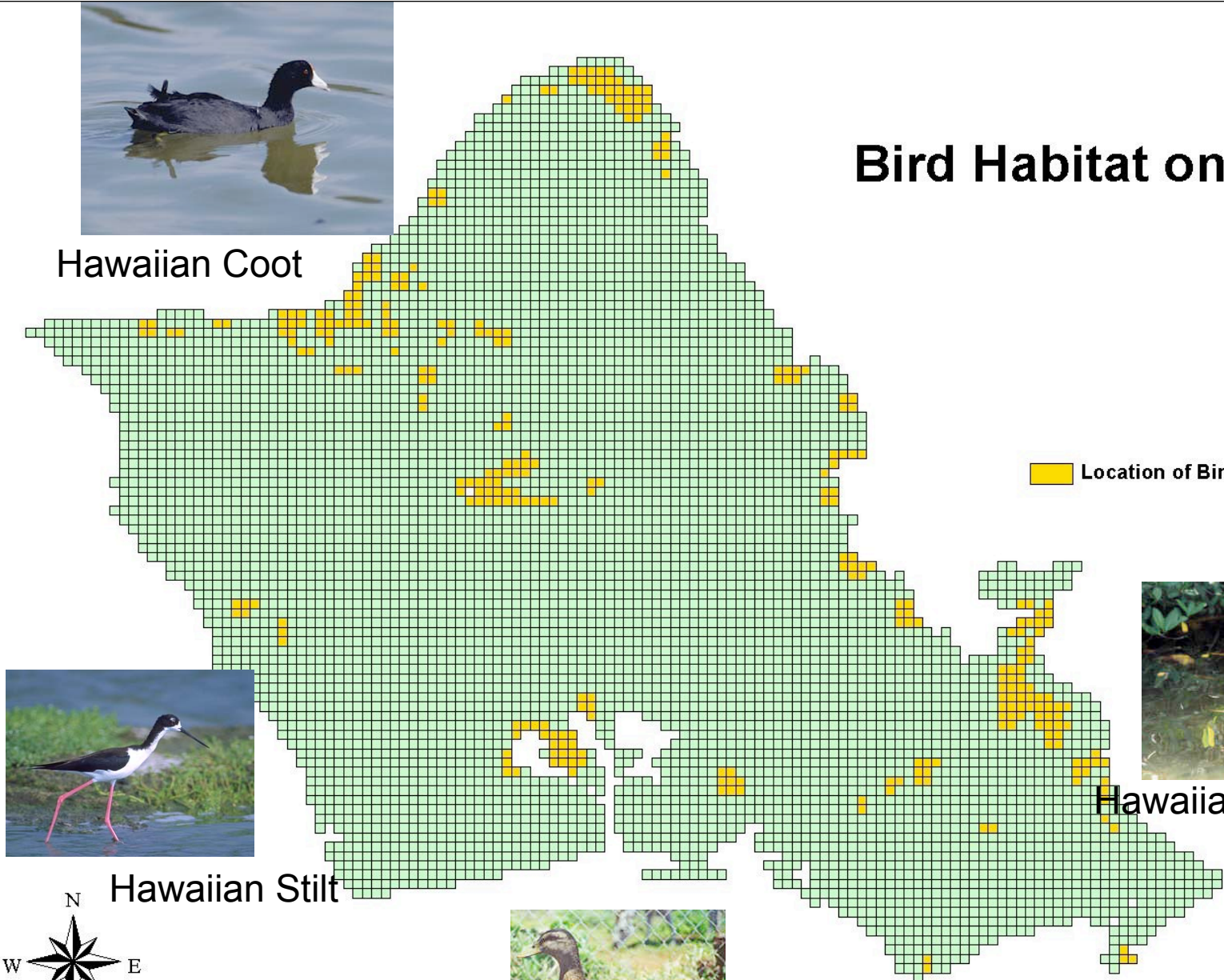
Wetlands
Yes

Population in area-C
0.001 - 478.283
478.283 - 987.337

Population in area-B
0.063 - 228.358
228.358 - 1257.894
1257.894 - 5641.15

Population in area-A
0.001 - 585.319
585.319 - 1813.265
1813.265 - 5823.345
Conservation

N
W E
S

0   5   10 Miles

Annual growth in area-A = 0%, B = 3%

Bird Habitat on Oahu

Hawaiian Coot

Hawaiian Stilt

Hawaiian Duck

Hawaiian Gallinule

Location of Bird Habitat

N
W   E
S

0   5   10   Miles
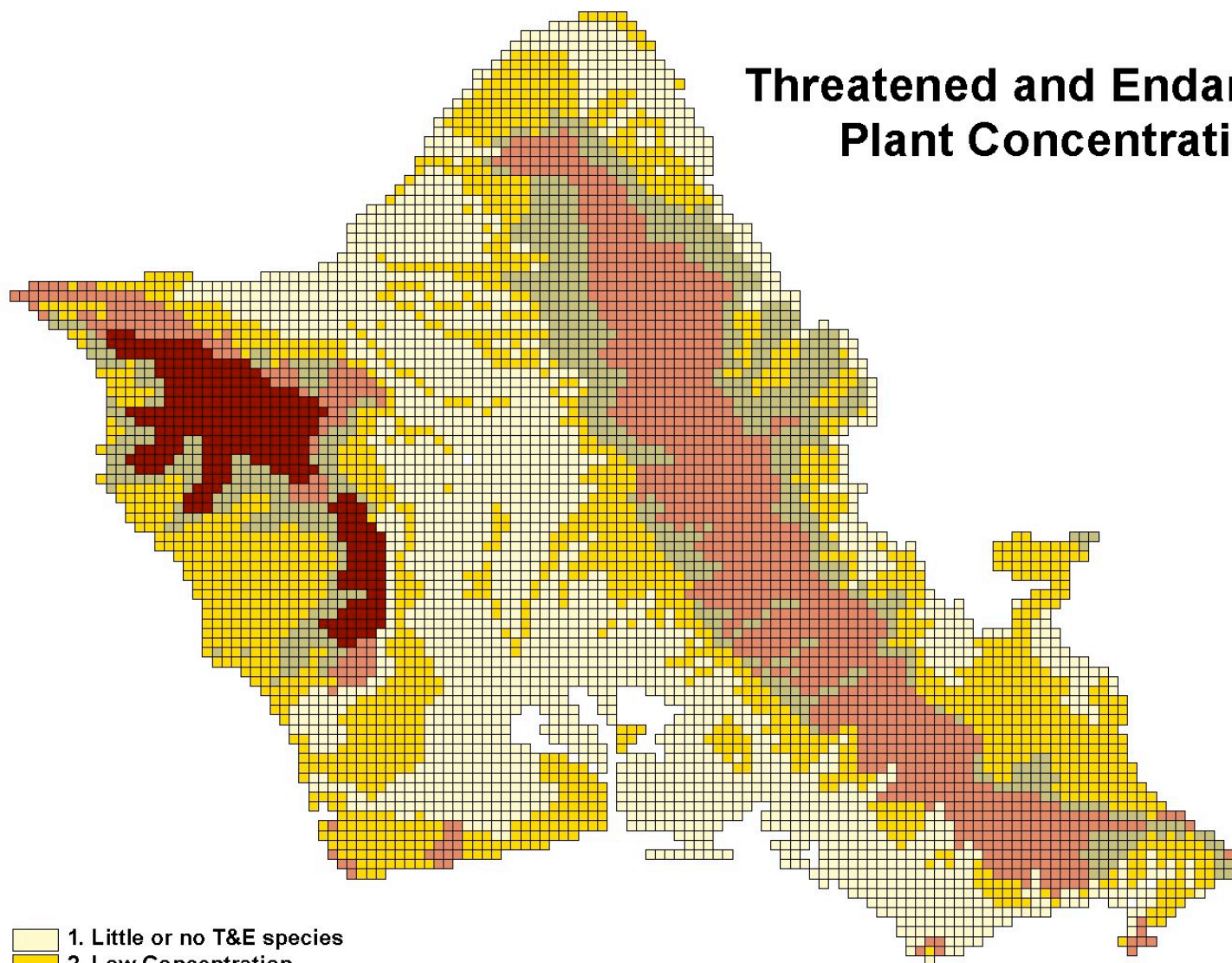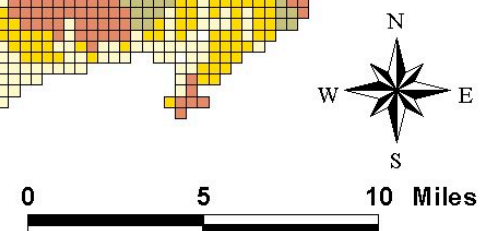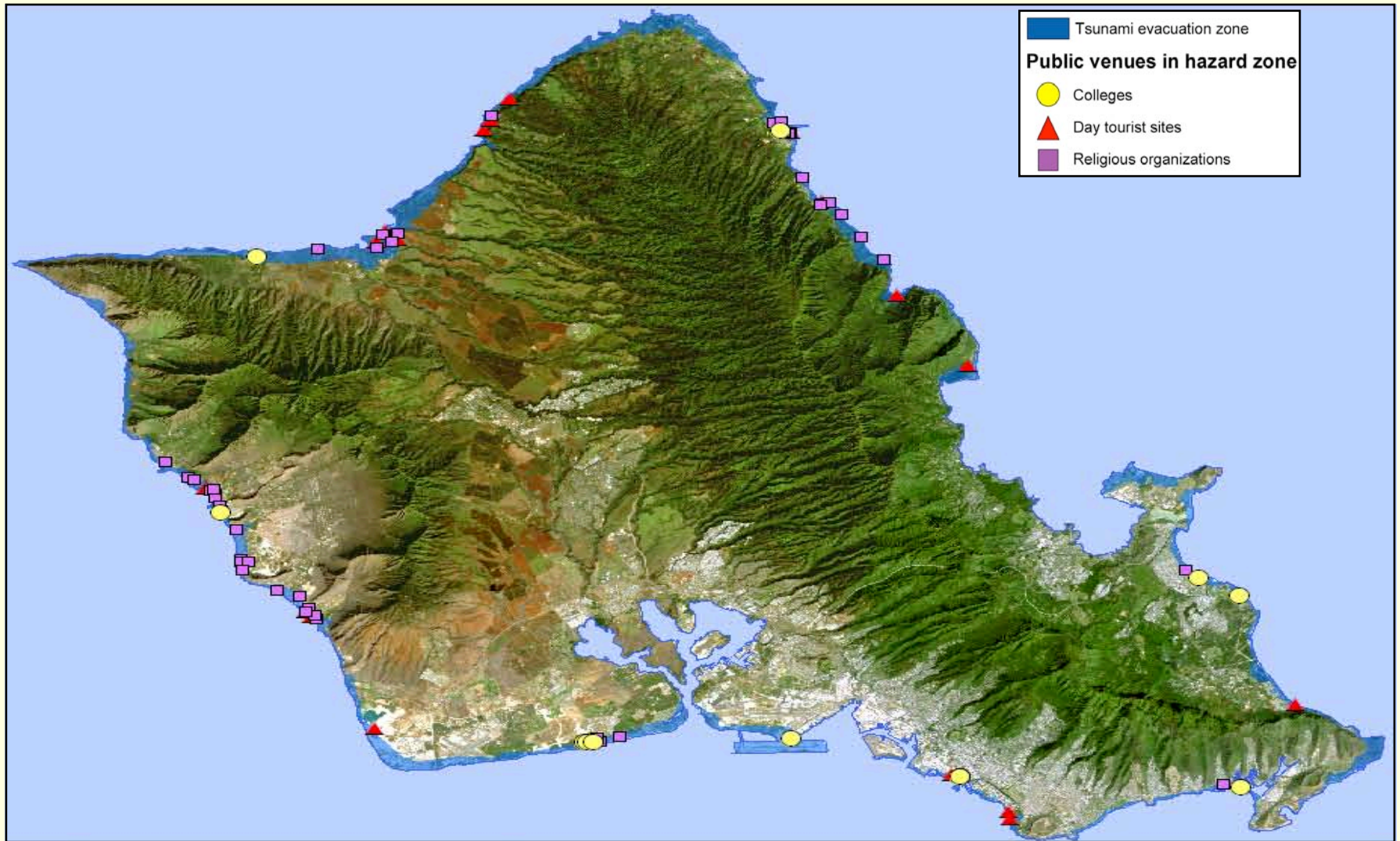
Threatened and Endangered Plant Concentration

1. Little or no T&E species
2. Low Concentration
3. Medium Concentration
4. High Concentration
5. Very High Concentration

N
W   E
S

0   5   10   Miles

# Public Facilities in Tsunami Zone

Incentives for Preservation

- **Conservation Banking**
- **Wetlands Banking**
- **Species Banking**
- **Earn development credits for preservation**
- **Similar to carbon credits**
- **Several hundred "mitigation banks" established on the mainland**

Summary & Conclusions

- I/O data to show relationship between economy and water/sewer/infrastructure ;
- Spatial data used to locate economic activity and development pressures
- "We have met the enemy…and he is us!"
- *"Less is more"*
- Increase densities to preserve open spaces, wildlife areas and to promote agriculture…

Invest in Sustainability Research

- Hawaii is a "small open economy"
- Influenced by exogenous factors
- Difficult to influence prices, production
- "Currency of ideas"
- Test bed for new technologies, approaches and concepts
- Partner with innovators like Iceland
- Poverty, environmental degradation, despair engulfing the world…
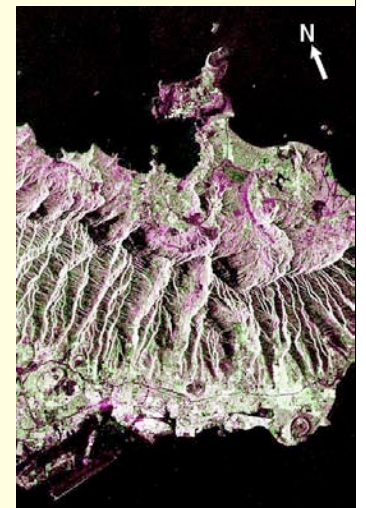
Look for Solutions from Within

- **Culturally appropriate system of land management (based on the Ahupua`a);**
- **Preservation of gathering rights, access to shoreline and mountain areas (PASH case);**
- **Public Trust doctrine (Waiahole Ditch Case);**
- **Balance between development, growth, environment, and the economy…**

Questions?

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