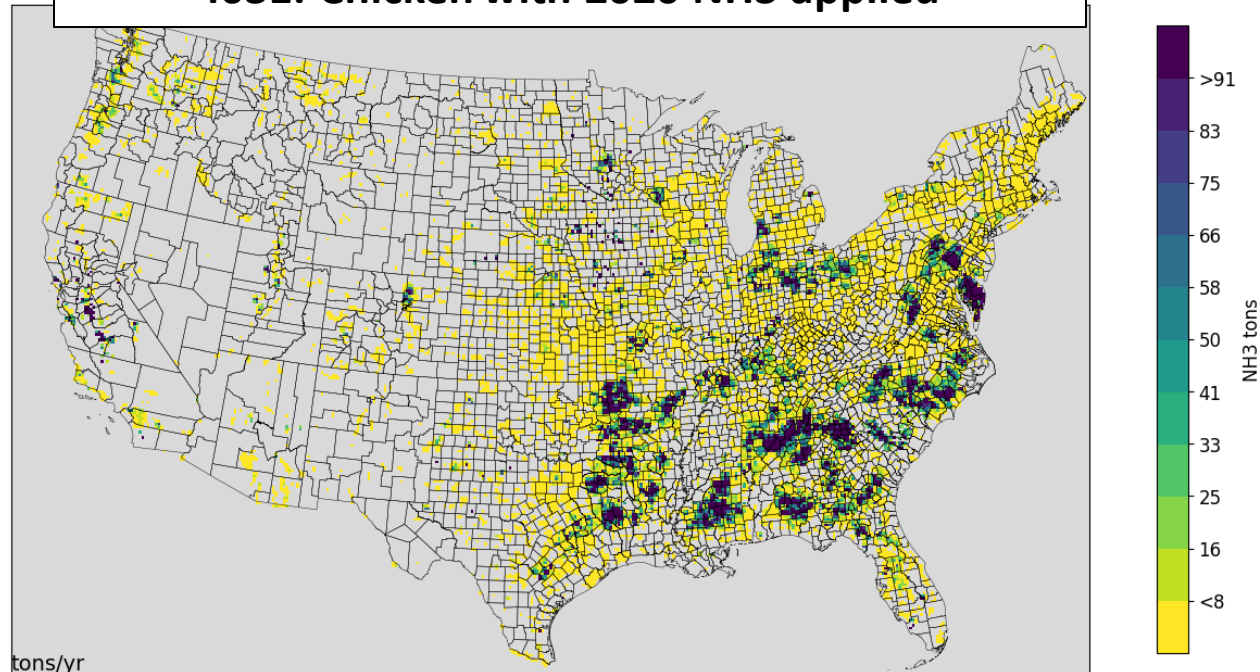


# Geospatial Gridding Surrogate Updates for the 2020 Emissions Modeling Platform

**4031: Chicken with 2020 NH<sub>3</sub> applied**



**James Beidler<sup>1</sup>, Alison Eyth<sup>2</sup>,  
Lindsay Dayton<sup>2</sup>, Tesh Rao<sup>2</sup>**

<sup>1</sup>ORD/CEMM/AESMD/ESAB;

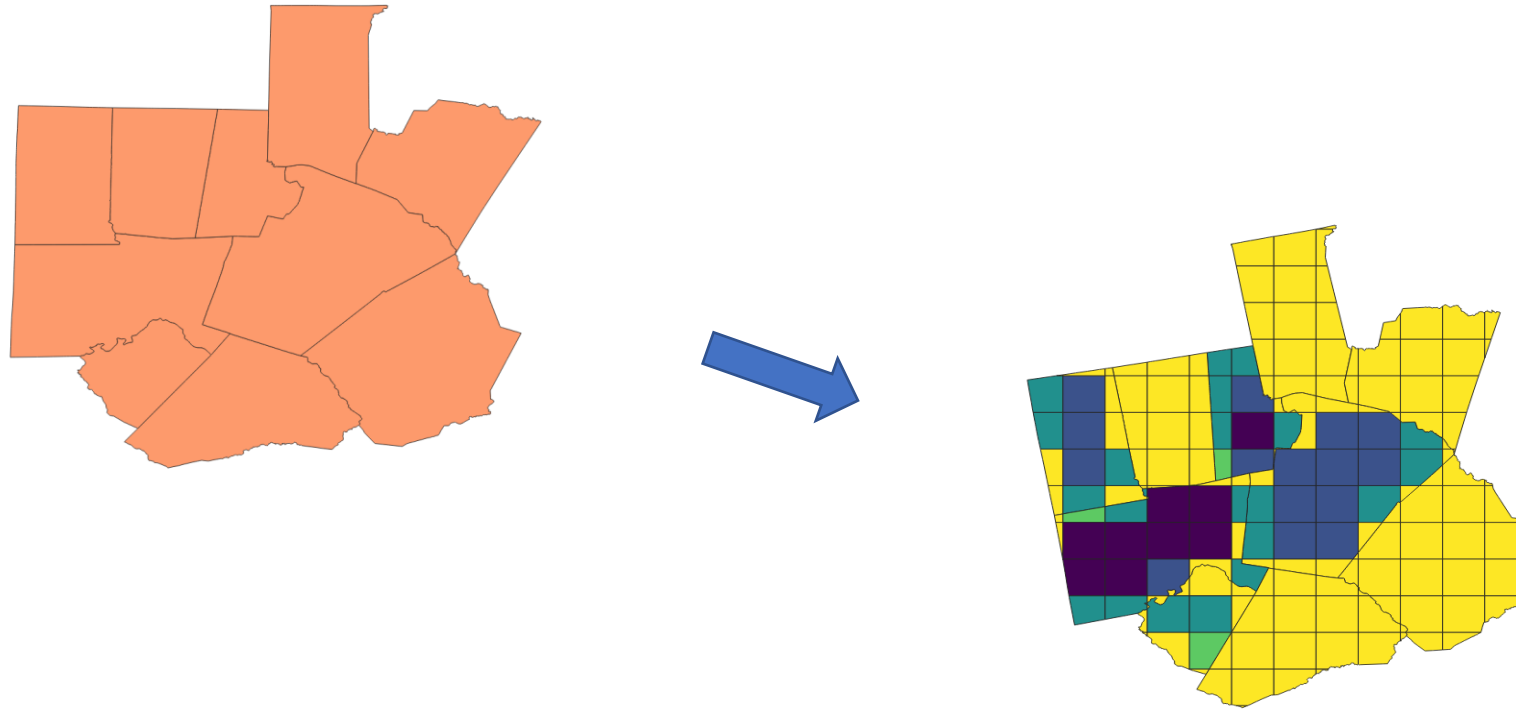
<sup>2</sup> OAQPS/AQAD/EIAG

For help accessing this  
document, email

[NEI\\_Help@epa.gov](mailto:NEI_Help@epa.gov)

# What is a Spatial Surrogate?

Spatial surrogates map area emissions to a gridded modeling domain using a weighting factor.

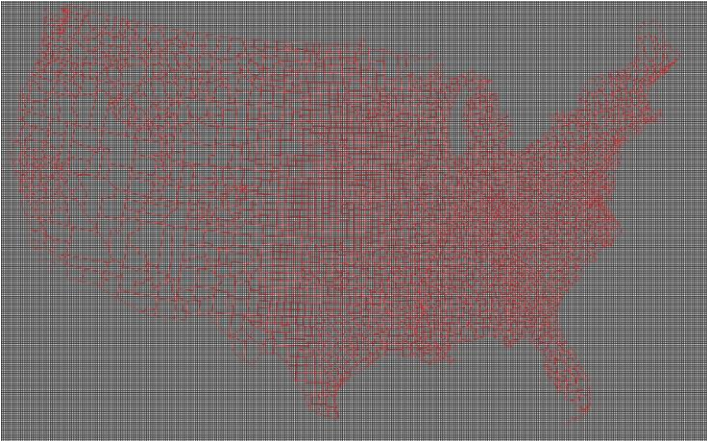


# What is a Spatial Surrogate?

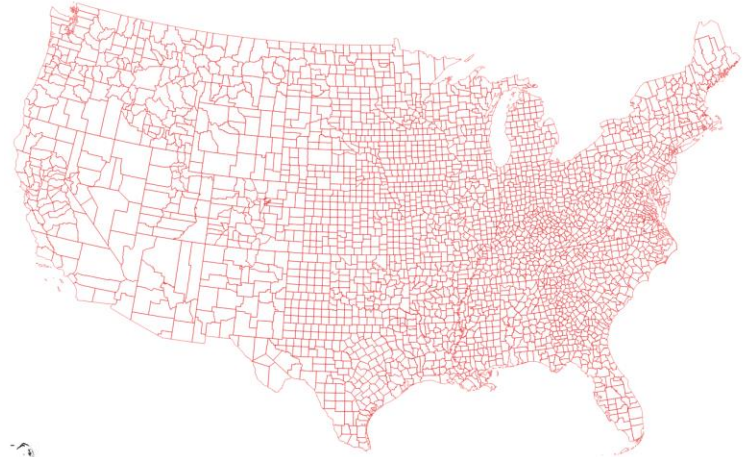
Spatial surrogates are produced for SMOKE using the Surrogate Tool

The Surrogate Tool processes three general categories of geospatial data

A modeling grid



Spatial Unit Data (Counties)



Weighting Attributes



The weighting and spatial unit data are typically in the form of shapefiles.

# Examples of Weighting Data Used for Spatial Surrogates

- **National Land Cover Database (NLCD)**
  - High resolution land cover data applied across most non-point sectors
- **American Community Survey (ACS)**
  - Census statistics over a five year period related to housing and population applied mainly to the general non-point (nonpt) sector
- **Food and Agriculture Organization (FAO) and National Pollutant Discharge Elimination System (NPDES)\***
  - FAO remote-sensed animal specific raster maps and NPDES water permits for AFOs applied to the livestock waste and fugitive dust sectors
- **OpenStreetMap (OSM)\***
  - Crowd-sourced attributes for road and parking surfaces, locations of fueling stations applied to the nonpt, solvents and fugitive dust sectors
- **USGS Mineral Resources Data System (MRDS)**
  - Locations and types of mines and quarries used for the nonpt sector

\* NEWLY USED FOR 2020 PLATFORM

# Updates to Spatial Surrogates

- Spatial surrogates are mapped to inventory data at the source category code (SCC) and/or county level using a gridding cross-reference
- Surrogates can be narrowly mapped (ie. Sand and Gravel quarry SCC to Sand and Gravel Surrogate) or broadly (i.e., Surface coating SCCs to NLCD Low+Med+High surrogate)
- Updates are made to the platform surrogates as year-specific and more granular weighting data becomes available
- The 2020 platform contained new and updated surrogates for livestock, fugitive dust (afdust), residential wood combustion (rwc), and some SCCs in nonpt, nonroad, and solvents

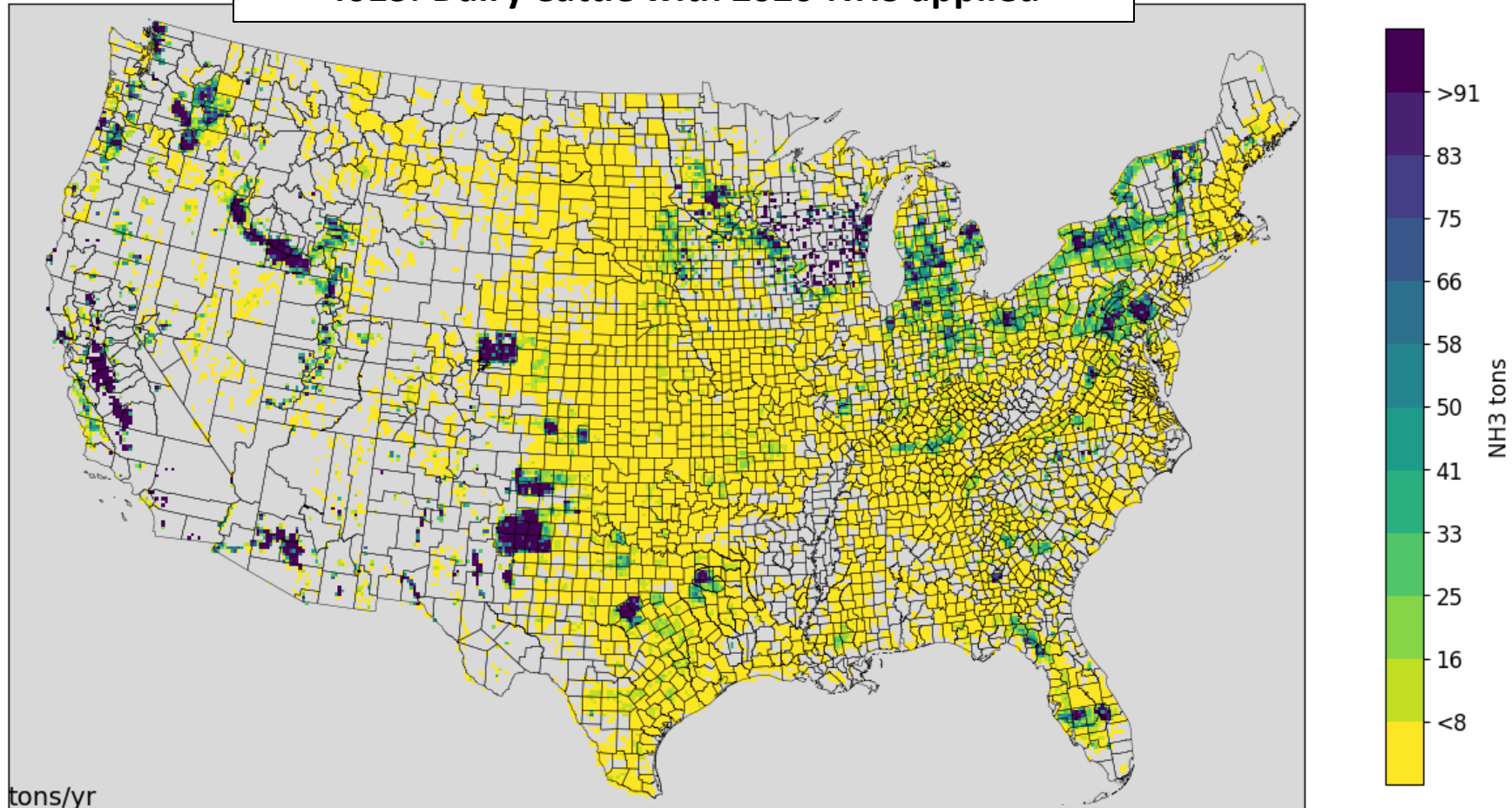
# Livestock Waste Surrogate Updates in 2020 Platform

- Previous platforms used NLCD agricultural land cover for all animals
- New surrogates use:
  - 2010 Animal-specific FAO raster data at ~10 km resolution masked with NLCD agriculture to improve fine scale resolution
  - National Pollutant Discharge Elimination System (NPDES) water waste animal feedlot operation (AFO) permits for states where publicly available
  - NPDES gap-filled with FAO data and NLCD agricultural land where NPDES state data was unavailable
- IA, NC, SC, MN, WI, CA have public NPDES point datasets with varying coverage by animal type
- Animal types with complete NPDES data in one or more state include beef cattle, dairy cattle, chicken, swine, sheep, horse, turkey

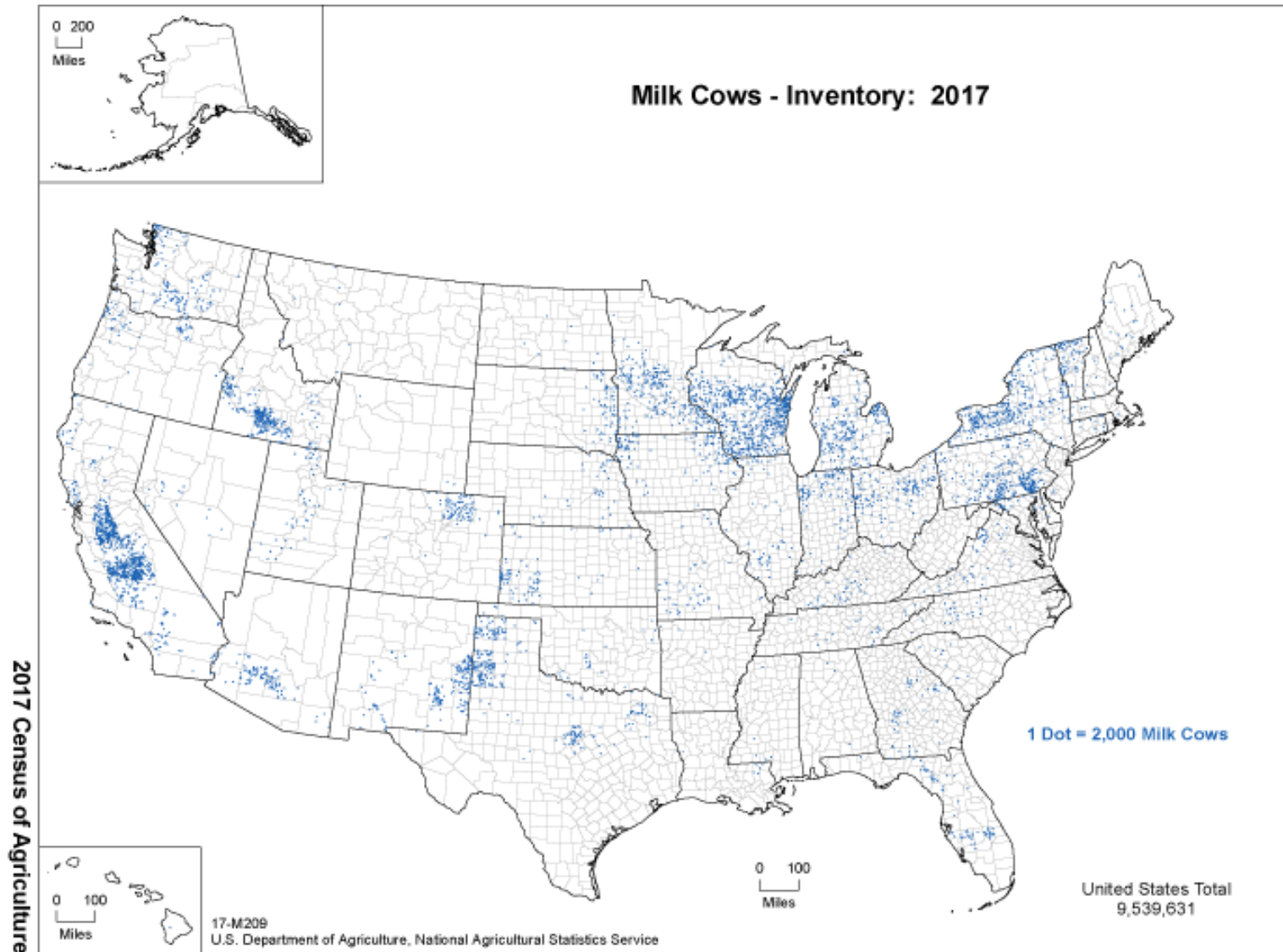


# Livestock Waste Surrogate Updates

4013: Dairy Cattle with 2020 NH<sub>3</sub> applied



- Key dairy states with NPDES data include California and Wisconsin
- Dairy cattle gapfilled with FAO cattle (population greater than 700 head per FAO raster pixel)



### 2017 USDA Milk Cow Population

- Livestock animal types with NPDES data were gap-filled with FAO data to give national coverage
- Spatial distribution validated against USDA livestock count plots w/ local geospatial analysis in high emission areas



# Livestock Waste Surrogate Updates

NC Swine

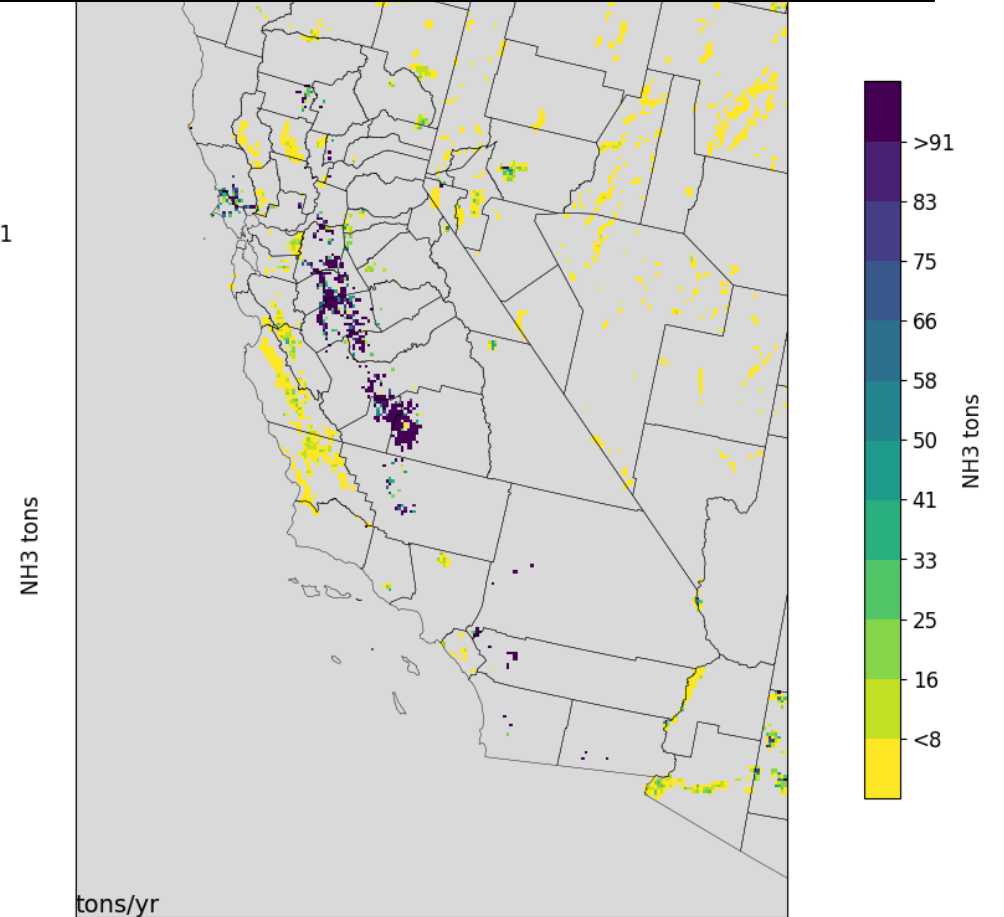


**4021: 4 km NPDES Swine 2020NEI NH3**

CA Dairies



**4013: 4 km NPDES Dairy Cattle 2020NEI NH3**



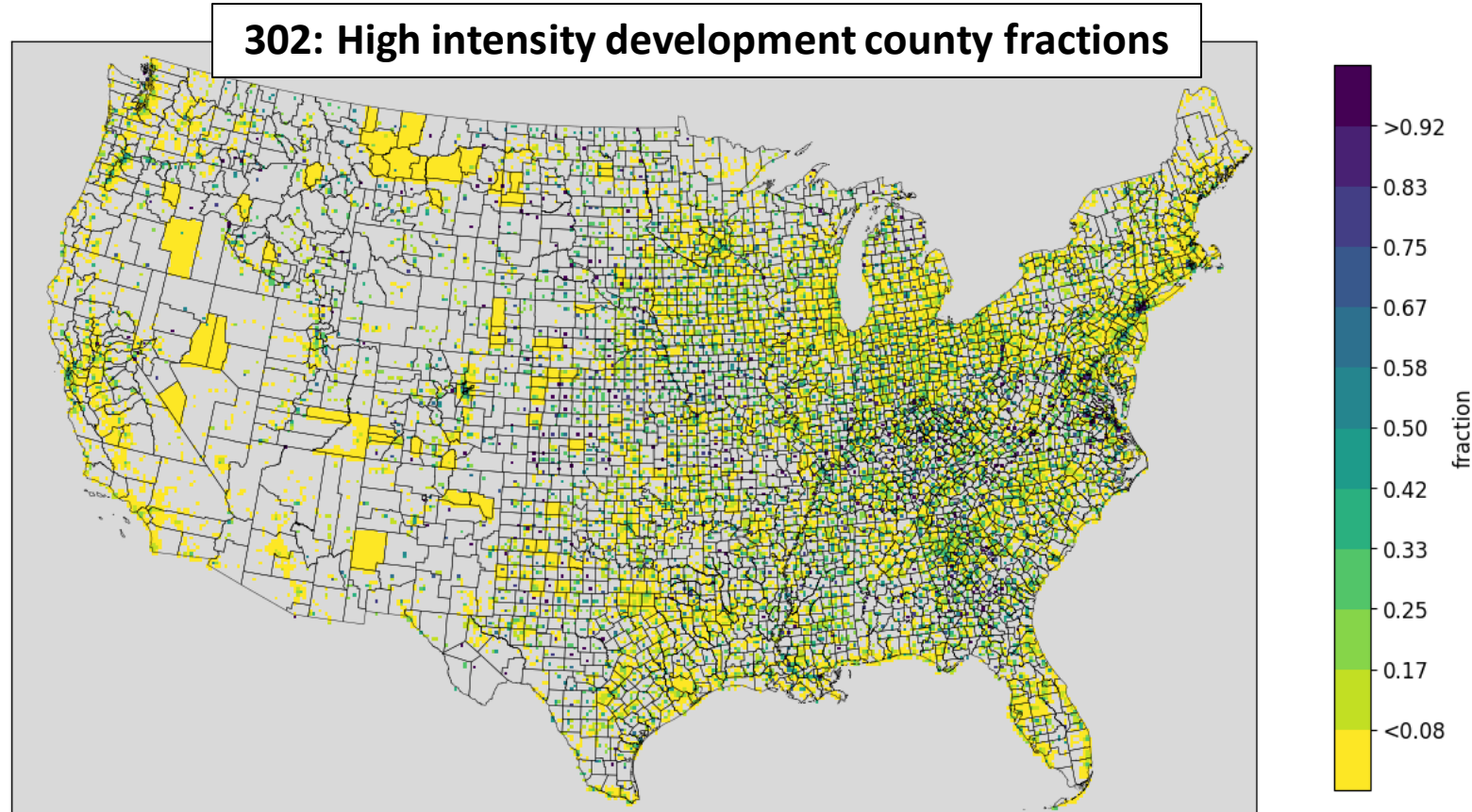
- 4 km surrogates of high emissions areas provided useful references for validation
- High resolution plots show the potential for fine scale modeling improvement

## 2020 NEI Livestock Waste Emissions by Surrogate

ID	Description	NH3	NOX	PM25	SO2	VOC
<b>405</b>	FAO 2010 Horse	31,969	0	0	0	2,558
<b>406</b>	FAO 2010 Sheep	19,235	0	0	0	1,539
<b>4012</b>	NPDES 2020 Beef Cattle	702,119	0	0	0	56,170
<b>4013</b>	NPDES 2020 Dairy Cattle	572,321	0	0	0	45,786
<b>4021</b>	NPDES 2020 Swine	838,696	0	0	0	67,096
<b>4031</b>	NPDES 2020 Chicken	426,996	0	0	0	34,157
<b>4041</b>	NPDES 2020 Goat	19,231	0	0	0	1,538
<b>4071</b>	NPDES 2020 Turkey	83,001	0	0	0	6,640

- The new livestock surrogates are used to spatially apportion over half of the approx. 5M tons NH3 in 2020 platform
- The livestock surrogates are also applied to livestock-related fugitive dust sources

# NLCD Land Cover Surrogate Updates



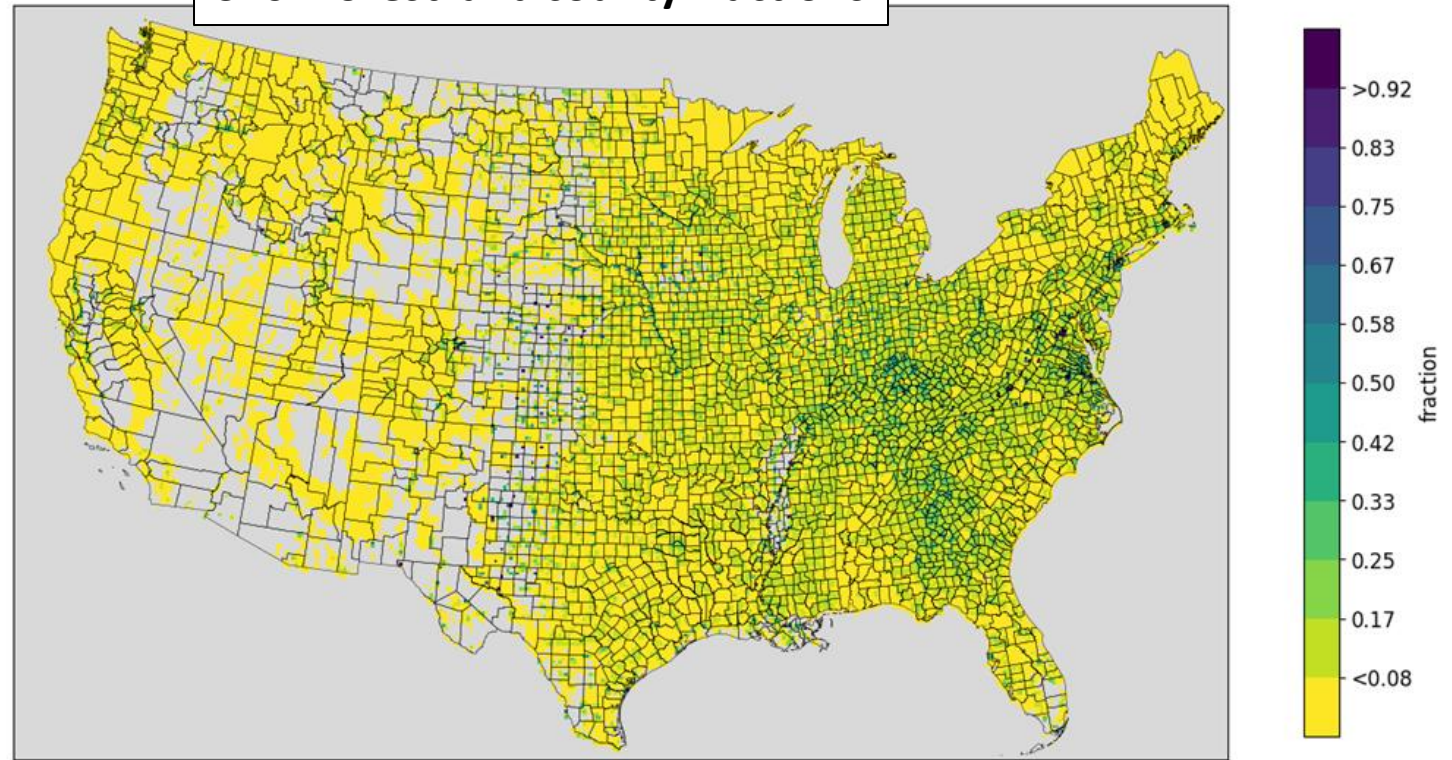
- National Land Cover (NCLD) data were updated to 2019 from 2011
  - Land use with percent developed impervious surface
  - Used to define land area, water, and development related surrogates
  - NLCD surrogates commonly used as a gapfiller for other surrogates
  - Downscaled to 250 m from 30 m using a nearest neighbor approach

# NLCD Land Cover Surrogate Updates

## Available NLCD Surrogates:

- Open Space (< 20% impervious)
- Low Development (20-49% impervious)
- Med Development (50-79% impervious)
- High Development (80%+ impervious)
- Combinations of Open, Low, Med, and High
- Total Agriculture (pasture, hay, row crops)
- Forest Land (all tree types)
- Recreational Land
- All Land
- All Water

## 320: Forest land county fractions



## Sources using NLCD surrogates:

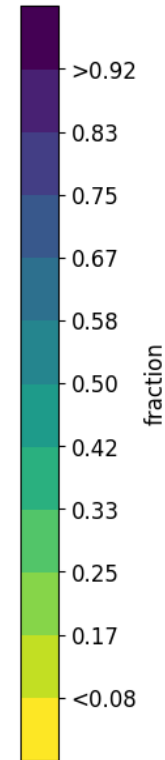
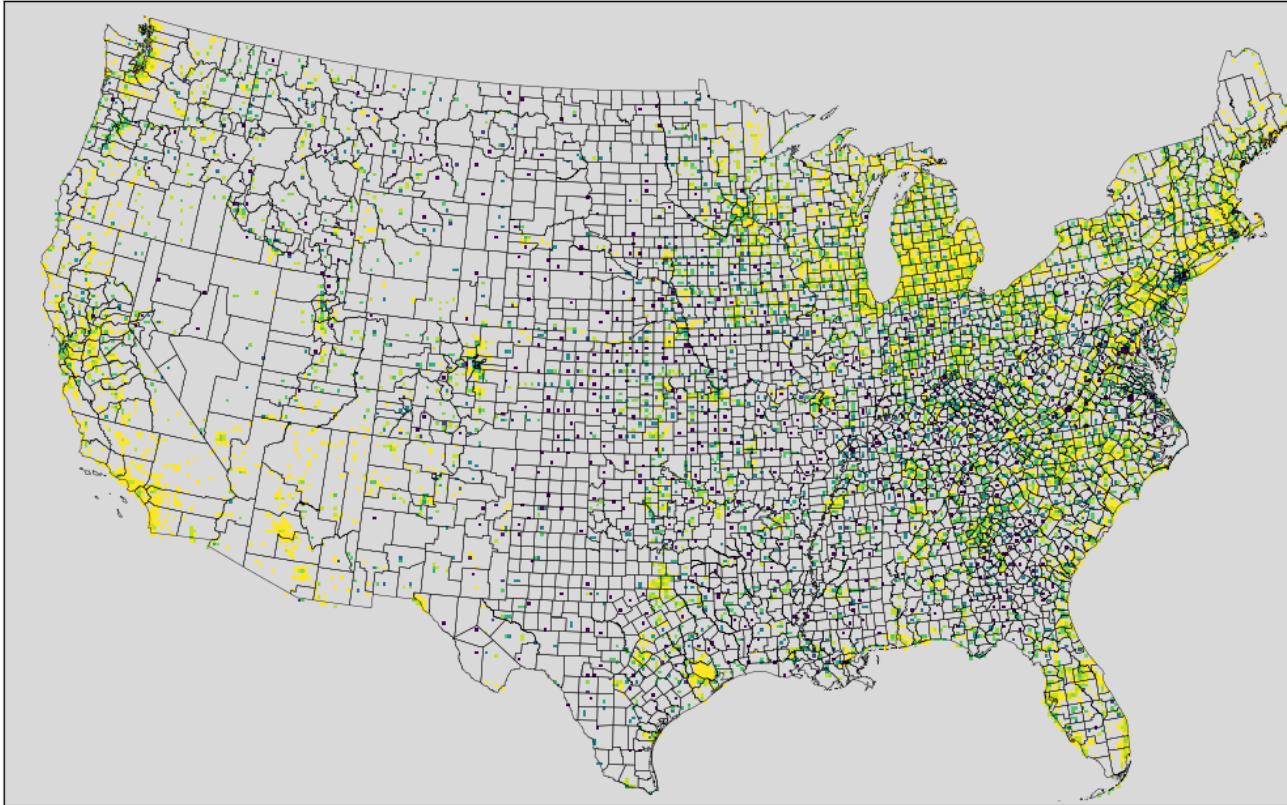
- Most nonroad and off-network onroad emissions
- All fertilizer emissions are assigned to NLCD Total agriculture
- 650k tons PM2.5 of various fugitive dust sources, 800k tons VOC of solvent sources
- Many other nonpoint sources of NOx and VOC

**Totals by CAP:** 1.4M tons NOx, 2M tons NH3, 1.3M tons PM2.5, 2.6M tons VOC, 104K tons SO2



# OpenStreetMap Surrogates

Surrogate 900: OSM Fuel

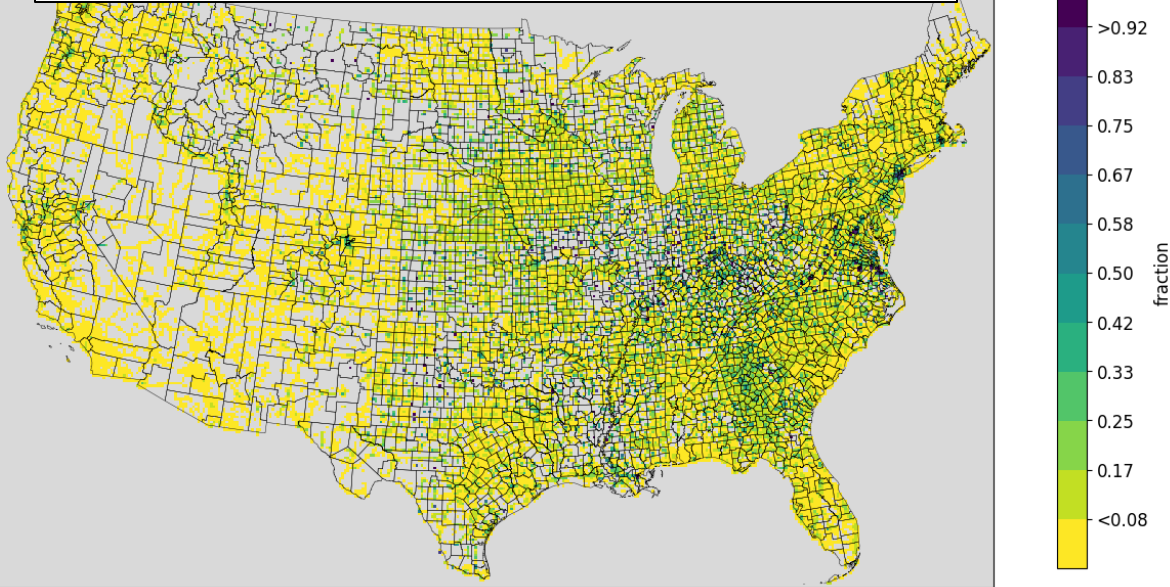


900: Fuel station county fractions

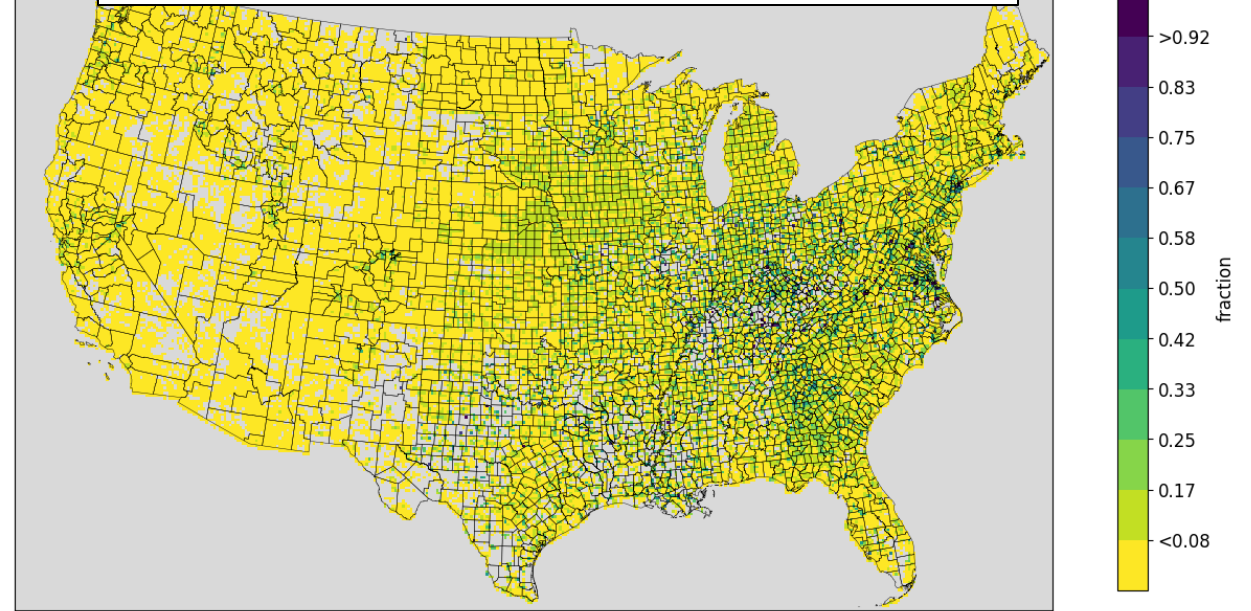
- Crowd-sourced global open geographic database
- Features extracted from OpenStreetMap database include:
  - **Fuel stations** as point amenities used for nonpt sector stage 1 tank filling
  - **Asphalt surfaces** as polygons and lines with asphalt surface type used for nonpt and solvent sector asphalt paving
  - **Unpaved roads** as lines with unpaved surface types used for fugitive dust (afdust) unpaved roads



**901: Asphalt surface county fractions**



**902: Unpaved road county fractions**



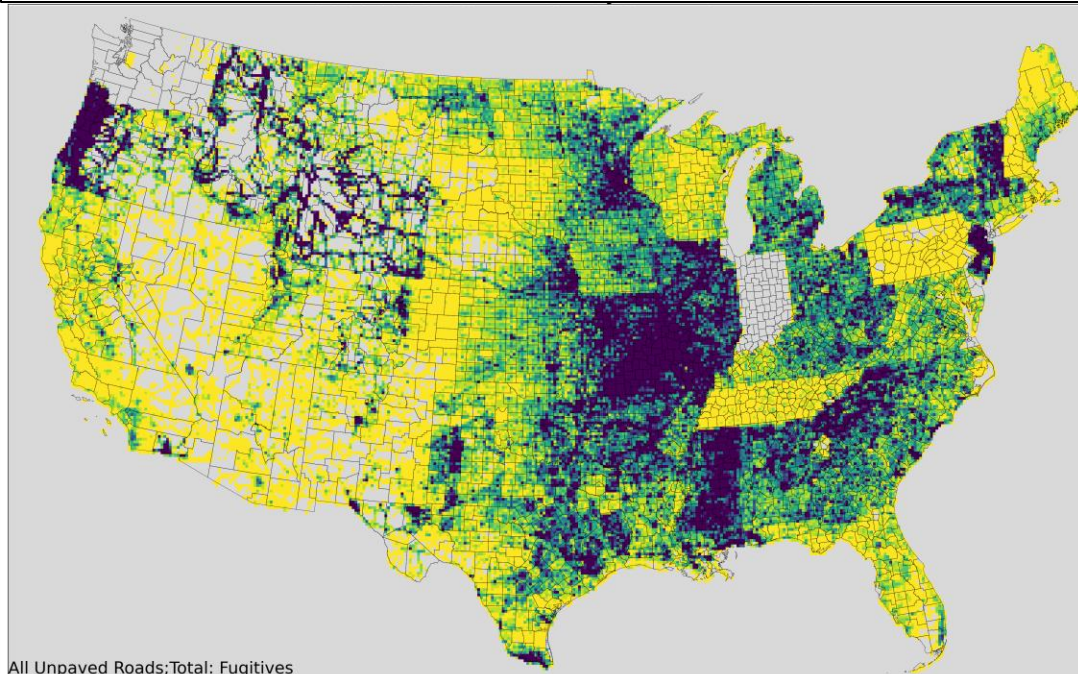
- OpenStreetMap is a feature dataset that does not indicate activity
- Coverage of data has regional variability

Emissions assigned to each surrogate by sector shown in table below

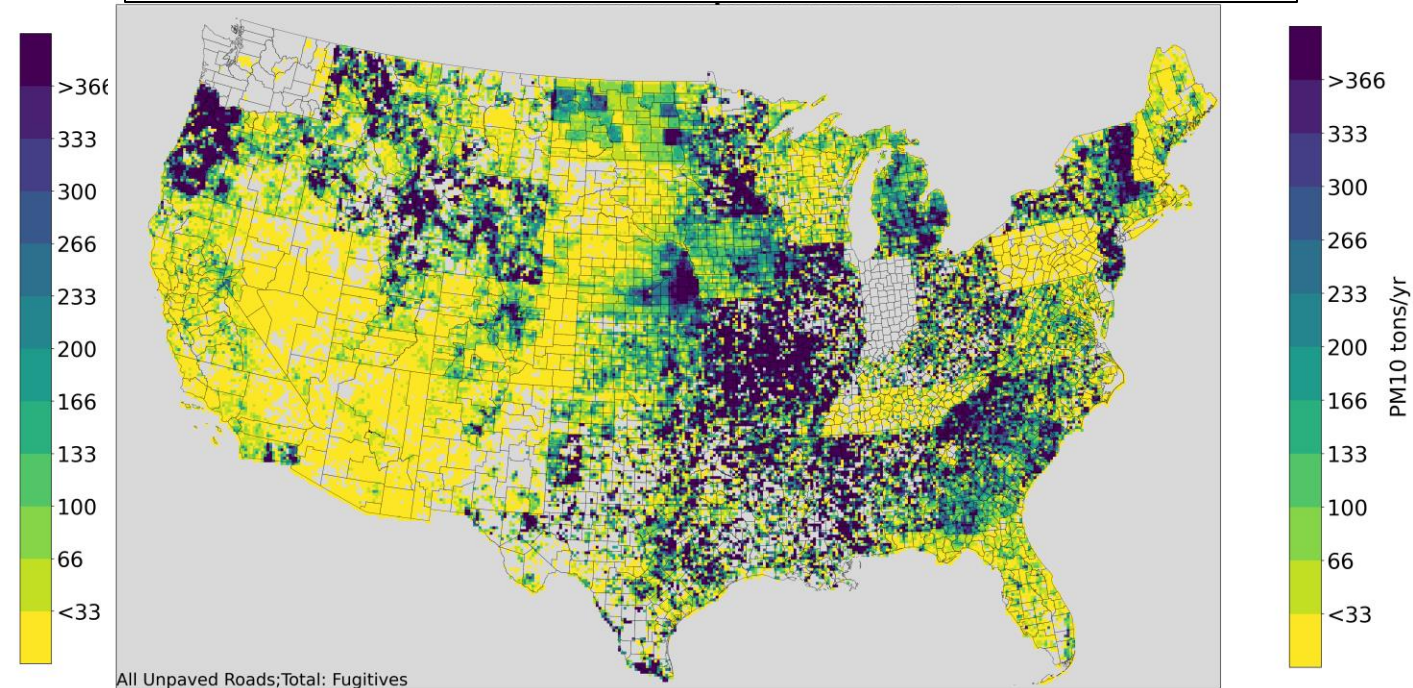
Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
afdust	902	OSM Unpaved Roads	0	0	960,028	0	0
nonpt	900	OSM Fuel	0	0	0	0	209,354
np_solvents	901	OSM Asphalt Surfaces	0	0	0	0	339,778

# Unpaved Road Surrogate 2017 to 2020 Spatial Allocation

**304: NLCD Open + Low 2020 NEI Unpaved Road PM10**



**902: OSM Unpaved Roads 2020 NEI Unpaved Road PM10**



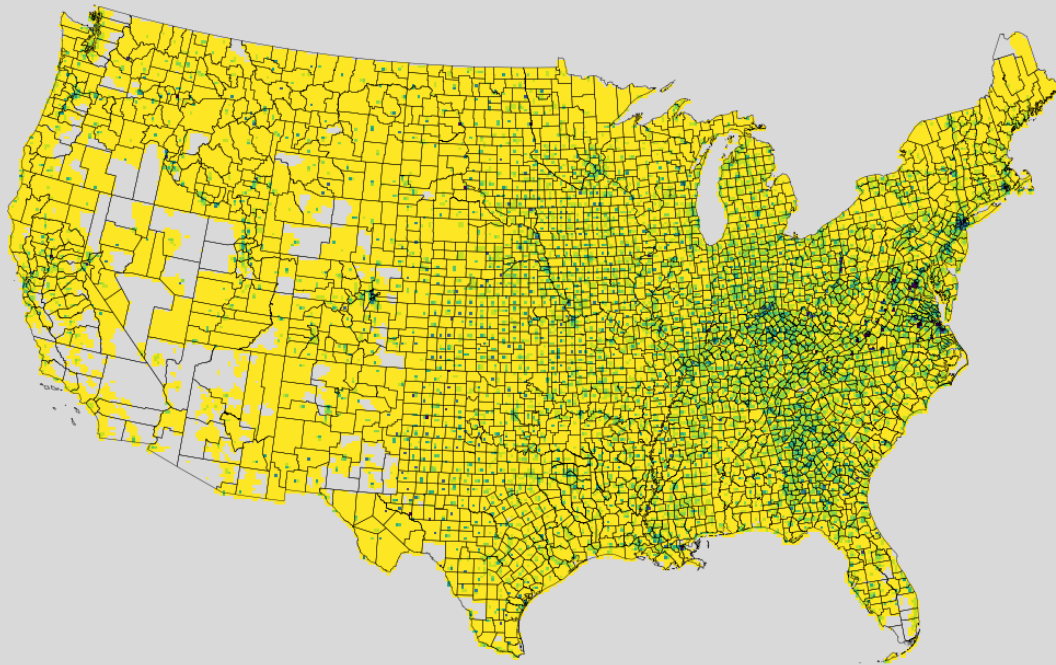
Change in spatial allocation for the 2020 NEI unpaved road fugitive dust PM10 emissions as applied to the

- 2017 platform surrogate 304: NLCD Open+Low (left)
- 2020 surrogate 902: OSM Unpaved Roads (right)

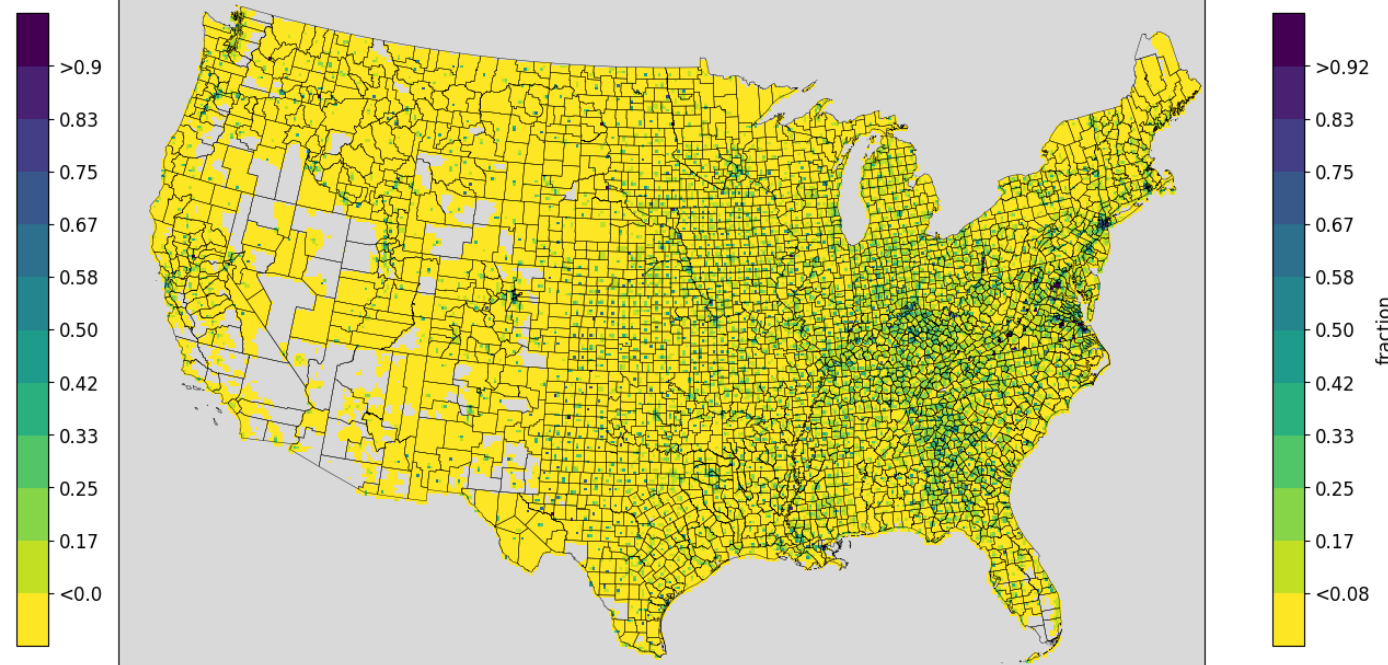


# American Community Survey Surrogate Updates

**135: Detached Housing county fractions**



**136: Single/Dual Unit Housing county fractions**

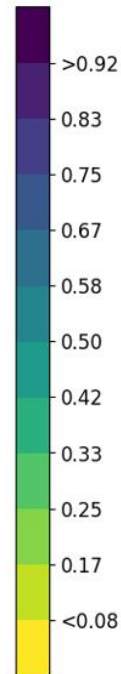
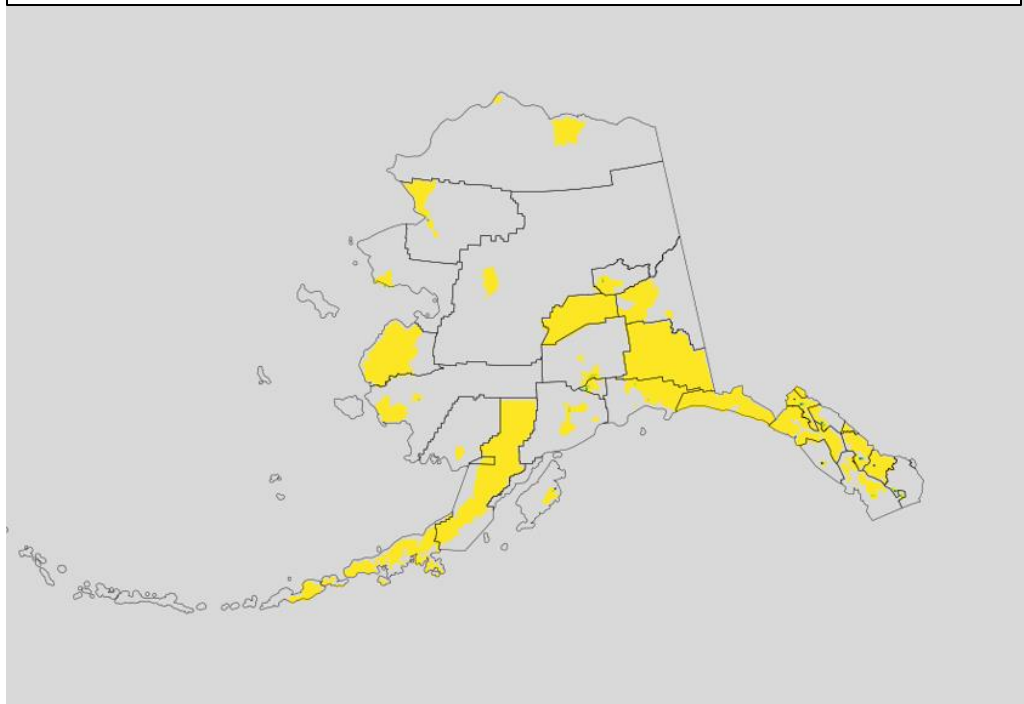


- 2020 release of 5-year data by census block group
- Population, housing, primary home heating (natural gas, oil, etc.)
- Detached homes and single/dual units
  - New surrogates used for some residential wood combustion sources in 2020

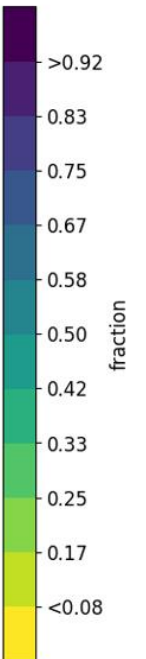
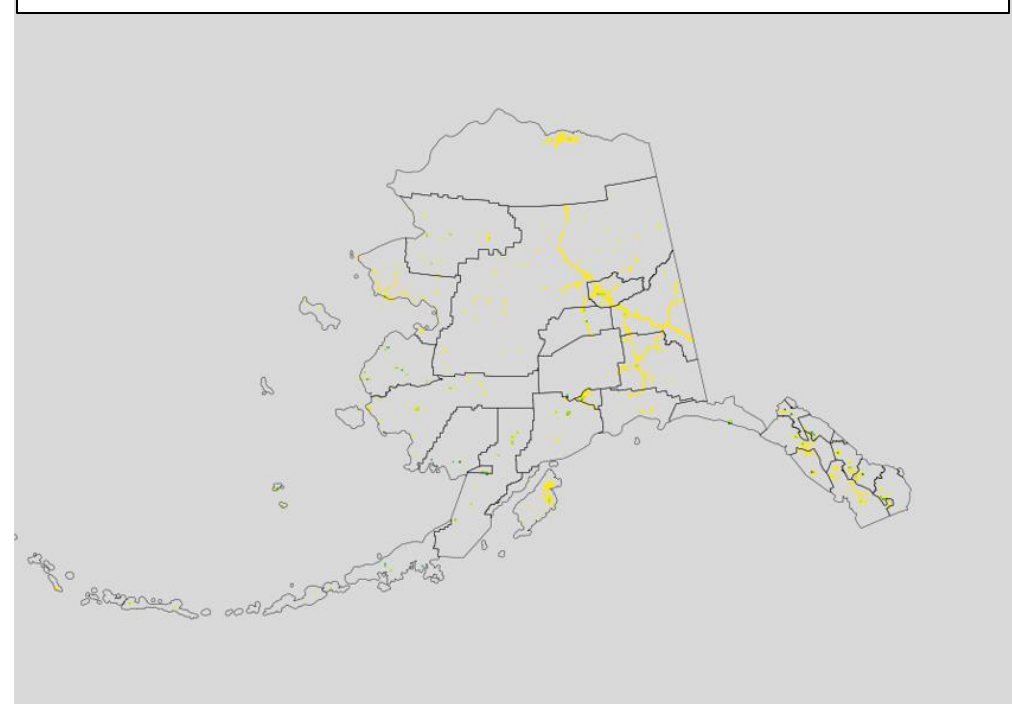
# Other Recent Updates

- 2020 year-specific oil and gas surrogates
- Additional mining surrogates: sand and gravel, lead, crushed stone
- 2020 TIGER county boundaries to capture new counties and FIPS
- 4 km CONUS and new AK, HI, and PR/VI surrogates

**100: Population county fractions**



**695: Well count – oil wells county fractions**



# Ongoing and potential updates for platforms after 2020

- Refinement of residential wood combustion (RWC) surrogates
- Creation of a recreational waters surrogate to reflect activity
- Parking surrogate to allocate exhaust and evaporative off-network mobile
- 2020 12 km and 4 km CONUS surrogates available from:  
[https://gaftp.epa.gov/Air/emismod/2020/spatial\\_surrogates/](https://gaftp.epa.gov/Air/emismod/2020/spatial_surrogates/)
- 2020 platform surrogate shapefile inputs available from:  
[https://gaftp.epa.gov/Air/emismod/2020/spatial\\_surrogates/shapefiles/](https://gaftp.epa.gov/Air/emismod/2020/spatial_surrogates/shapefiles/)



Contact: James Beidler [Beidler.James@epa.gov](mailto:Beidler.James@epa.gov)

**The views expressed in this presentation are those of the author(s) and do not necessarily represent the views or the policies of the U.S. Environmental Protection Agency.**

# Reference Slides

# Top 15 Surrogates for CAPs

Surrogate	NH3	NOX	PM2_5	SO2	VOC	ALL CAPS
NLCD Total Agriculture	1,833,469	257,391	521,516	197	181,096	2,793,669
NLCD Med + High	19,120	503,164	437,296	85,883	675,979	1,721,442
All Unrestricted AADT	54,906	1,215,064	45,715	6,043	394,564	1,716,292
NLCD All Development	80,094	240,831	150,808	11,547	1,022,344	1,505,624
Population	454	0	0	0	1,405,603	1,406,057
OSM Unpaved Roads	0	0	960,028	0	0	960,028
NPDES 2020 Beef Cattle	702,119	0	191,878	0	56,170	950,167
All Restricted AADT	29,464	783,301	20,867	3,049	103,641	940,322
NPDES 2020 Swine	838,696	0	658	0	67,096	906,450
Well Count - Oil Wells	0	159,345	4,270	104,961	619,896	888,472
Oil Production at Oil Wells	0	3,060	4	26,019	805,474	834,557
Single and Dual Unit Housing	15,780	46,570	318,302	8,430	421,911	810,993
Well Count - Gas Wells	0	281,181	4,185	212	504,727	790,305
NPDES 2020 Dairy Cattle	572,321	0	15,033	0	45,786	633,140
NLCD Low + Med + High	1,725	260,644	162,104	5,943	115,228	545,644

# Updated cross-references for 2020

Sector	SCC	SCC Description	Surrogate Code	Surrogate Description	New Surrogate	New Surrogate Description
livestock	2802004001	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Storage	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2802004002	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Mixing	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2802004003	Miscellaneous Area Sources; Agricultural Crop Usage; Agriculture Silage; Feeding	310	NLCD Total Agriculture	4011	Large Cattle Operations
livestock	2805002000	Miscellaneous Area Sources; Agriculture Production - Livestock; Beef cattle production c	310	NLCD Total Agriculture	4012	Beef cattle
livestock	2805007100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry Waste; Poultry P	310	NLCD Total Agriculture	4031	Chicken
livestock	2805009100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry production - bro	310	NLCD Total Agriculture	4031	Chicken
livestock	2805010100	Miscellaneous Area Sources; Agriculture Production - Livestock; Poultry production - turk	310	NLCD Total Agriculture	4071	Turkey
livestock	2805018000	Miscellaneous Area Sources; Agriculture Production - Livestock; Dairy cattle composite; n	310	NLCD Total Agriculture	4013	Dairy cattle
livestock	2805025000	Miscellaneous Area Sources; Agriculture Production - Livestock; Swine production compo	310	NLCD Total Agriculture	4021	Swine
livestock	2805035000	Miscellaneous Area Sources; Agriculture Production - Livestock; Horses and Ponies Waste	310	NLCD Total Agriculture	405	Horse
livestock	2805040000	Miscellaneous Area Sources; Agriculture Production - Livestock; Sheep and Lambs Waste	310	NLCD Total Agriculture	406	Sheep
livestock	2805045000	Miscellaneous Area Sources; Agriculture Production - Livestock; Goats Waste Emissions;	310	NLCD Total Agriculture	4041	Goat
afdust	2805100010	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4012	Beef cattle
afdust	2805100020	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4013	Dairy cattle
afdust	2805100030	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4031	Chicken
afdust	2805100040	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4031	Chicken
afdust	2805100050	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4021	Swine
afdust	2805100060	Miscellaneous Area Sources; Agriculture Production - Livestock; Dust kicked up by Livest	310	NLCD Total Agriculture	4071	Turkey
afdust	2325030000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Sand and Gravel; Total	306	NLCD Med + High	861	Sand and Gravel Mines
afdust	2325060000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Lead Ore Mining and Millin	306	NLCD Med + High	862	Lead Mines
afdust	2325020000	Industrial Processes; Mining and Quarrying: SIC 10 and SIC 14; Crushed and Broken Stone	306	NLCD Med + High	863	Crushed Stone Mines
afdust	2296000000	Mobile Sources; Unpaved Roads; All Unpaved Roads; Total: Fugitives	304	NLCD Open + Low	902	Unpaved roads
solvents	2461022000	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Emulsified Asphalt; Total	307	NLCD All Development	901	Asphalt surfaces
nonpt	2501060051	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations

# Updated surrogate cross-references for 2020

Sector	SCC	SCC Description	Surrogate Code	Surrogate Description	New Surrogate	New Surrogate Description
nonpt	2461025100	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Asphalt Paving: Hot and V	307	NLCD All Development	901	Asphalt surfaces
solvents	2461021000	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Cutback Asphalt; Total: A	307	NLCD All Development	901	Asphalt surfaces
nonpt	2501060201	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations
nonpt	2501060053	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stati	239	Total Road AADT	900	Gas stations
nonpt	2461025200	Solvent Utilization; Miscellaneous Non-industrial: Commercial; Asphalt Paving: Hot and V	307	NLCD All Development	901	Asphalt surfaces
rcw	2104008310	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, non-E	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
nonroad	2265004033	Mobile Sources; Off-highway Vehicle Gasoline; Lawn and Garden Equipment; 4-Stroke La	305	NLCD Low + Med	136	Single and Dual Unit Housing
rcw	2104008320	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, EPA c	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008620	Stationary Source Fuel Combustion; Residential; Wood; Hydronic heater: indoor	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008330	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, EPA c	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008510	Stationary Source Fuel Combustion; Residential; Wood; Furnace: Indoor, cordwood-fired	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008210	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; no	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008220	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; EP	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008300	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: freestanding, gener	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104009000	Stationary Source Fuel Combustion; Residential; Firelog; Total: All Combustor Types	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008230	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: fireplace inserts; EP	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
rcw	2104008100	Stationary Source Fuel Combustion; Residential; Wood; Fireplace: general	300	NLCD Low Intensity Deve	136	Single and Dual Unit Housing
nonpt	2610030000	Waste Disposal, Treatment, and Recovery; Open Burning; Residential; Household Waste	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008610	Stationary Source Fuel Combustion; Residential; Wood; Hydronic heater: outdoor	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008700	Stationary Source Fuel Combustion; Residential; Wood; Outdoor wood burning device, N	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008400	Stationary Source Fuel Combustion; Residential; Wood; Outdoor wood burning device, N	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008400	Stationary Source Fuel Combustion; Residential; Wood; Woodstove: pellet-fired, general	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008530	Stationary Source Fuel Combustion; Residential; Wood; Furnace: Indoor, pellet-fired, gen	300	NLCD Low Intensity Deve	135	Detached Housing
rcw	2104008630	Stationary Source Fuel Combustion; Residential; Wood; Hydronic heater: pellet-fired	300	NLCD Low Intensity Deve	135	Detached Housing



# Surrogate Definitions

REGION	SURROGATE	SURROGATE CODE	DATA SHAPEFILE	DATA ATTRIBUTE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE	WEIGHT FUNCTION	FILTER FUNCTION
USA	Population	100	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	POP2020		
USA	Housing	110	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	HU2020		
USA	Detached Housing	135	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	detachedh		
USA	Single and Dual Unit Housing	136	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	lttriunit		
USA	Residential Heating - Natural Gas	150	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	UTIL_GAS		
USA	Residential Heating - Distillate Oil	170	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	FUEL_OIL		
USA	Residential Heating - Coal	180	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	COAL		
USA	Residential Heating - LP Gas	190	cb_2020_us_county_500k	geoid	ACS_2020_5YR_BG_pop_hu	LP_GAS		
USA	Extended Idle Locations	205	cb_2020_us_county_500k	geoid	pil_2019_06_24	rev_truck		rev_truck>0
USA	Total Road AADT	239	hpms2017_v3_04052020	fips	hpms2017_v3_04052020	aadt		moves2014 IN ('02','03','04','05')
USA	Total Road Miles	240	hpms2017_v3_04052020	fips	hpms2017_v3_04052020	NONE		moves2014 IN ('02','03','04','05')
USA	All Restricted AADT	242	hpms2017_v3_04052020	fips	hpms2017_v3_04052020	aadt		moves2014 IN ('02','04')
USA	All Unrestricted AADT	244	hpms2017_v3_04052020	fips	hpms2017_v3_04052020	aadt		moves2014 IN ('03','05')
USA	Transit Bus Terminals	259	cb_2020_us_county_500k	geoid	ntad_2016_ipcd	NONE		bus_t=1
USA	Total Railroad Miles	260	cb_2020_us_county_500k	geoid	tiger_2014_rail	NONE		
USA	NTAD Total Railroad Density	261	cb_2020_us_county_500k	geoid	ntad_2014_rail_fixed	dens		RAILTYPE IN (1,2,3)

# Surrogate Definitions

REGION	SURROGATE	SURROGATE CODE	DATA SHAPEFILE	DATA ATTRIBUTE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE	WEIGHT FUNCTION	FILTER FUNCTION
USA	NTAD Class 1 2 3 Railroad Density	271	cb_2020_us_county_500k	geoid	ntad_2014_rail_fixed	dens	USA	NTAD Class 1 2 3 Railroad Density
USA	NLCD Low Intensity Development	300	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Low Intensity Development
USA	NLCD Open + Low	304	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Open + Low
USA	NLCD Low + Med	305	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Low + Med
USA	NLCD Med + High	306	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Med + High
USA	NLCD All Development	307	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD All Development
USA	NLCD Low + Med + High	308	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Low + Med + High
USA	NLCD Open + Low + Med	309	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Open + Low + Med
USA	NLCD Total Agriculture	310	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Total Agriculture
USA	NLCD Pasture Land	318	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Pasture Land
USA	NLCD Crop Land	319	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Crop Land
USA	NLCD Forest Land	320	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Forest Land
USA	NLCD Recreational Land	321	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Recreational Land
USA	NLCD Land	340	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Land
USA	NLCD Water	350	cb_2020_us_county_500k	geoid	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	USA	NLCD Water

# Surrogate Definitions

REGION	SURROGATE	SURROGATE CODE	DATA SHAPEFILE	DATA ATTRIBUTE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE	WEIGHT FUNCTION	FILTER FUNCTION
USA	FAO 2010 Cattle	401	cb_2020_us_county_500k	geoid	fao_Cattle_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Cattle
USA	FAO 2010 Large Cattle Operations	4011	cb_2020_us_county_500k	geoid	fao_LargeCattle_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Large Cattle Operations
USA	NPDES 2020 Beef Cattle	4012	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Beef Cattle
USA	NPDES 2020 Dairy Cattle	4013	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Dairy Cattle
USA	FAO 2010 Pig	402	cb_2020_us_county_500k	geoid	fao_Pig_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Pig
USA	NPDES 2020 Swine	4021	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Swine
USA	FAO 2010 Chicken	403	cb_2020_us_county_500k	geoid	fao_Chicken_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Chicken
USA	NPDES 2020 Chicken	4031	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Chicken
USA	FAO 2010 Goat	404	cb_2020_us_county_500k	geoid	fao_Goat_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Goat
USA	NPDES 2020 Goat	4041	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Goat
USA	FAO 2010 Horse	405	cb_2020_us_county_500k	geoid	fao_Horse_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Horse
USA	FAO 2010 Sheep	406	cb_2020_us_county_500k	geoid	fao_Sheep_2010_Da_nlcdproj_masked	DN	USA	FAO 2010 Sheep
USA	NPDES 2020 Turkey	4071	cb_2020_us_county_500k	geoid	livestock_npdes_state_permits_subset	Population	USA	NPDES 2020 Turkey
USA	Refineries and Tank Farms	650	cb_2020_us_county_500k	geoid	eia_2015_us_oil	NONE	USA	Refineries and Tank Farms
USA	Spud Count - CBM Wells	670	cb_2020_us_county_500k	GEOID	SPUD_CBM_CONUS_2020	ACTIVITY	USA	Spud Count - CBM Wells

# Surrogate Definitions

REGION	SURROGATE	SURROGATE CODE	DATA SHAPEFILE	DATA ATTRIBUTE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE	WEIGHT FUNCTION	FILTER FUNCTION
USA	Spud Count - Gas Wells	671	cb_2020_us_county_500k	GEOID	SPUD_GAS_CONUS_2020	ACTIVITY	USA	Spud Count - Gas Wells
USA	Gas Production at Oil Wells	672	cb_2020_us_county_500k	GEOID	ASSOCIATED_GAS_PRODUCTION_CONUS_2020	ACTIVITY	USA	Gas Production at Oil Wells
USA	Oil Production at CBM Wells	673	cb_2020_us_county_500k	GEOID	CONDENSATE_CBM_PRODUCTION_CONUS_2020	ACTIVITY	USA	Oil Production at CBM Wells
USA	Unconventional Well Completion Counts	674	cb_2020_us_county_500k	GEOID	COMPLETIONS_UNCONVENTIONAL_CONUS_2020	ACTIVITY	USA	Unconventional Well Completion Counts
USA	Well Count - All Producing	676	cb_2020_us_county_500k	GEOID	TOTAL_PROD_WELL_CONUS_2020	ACTIVITY	USA	Well Count - All Producing
USA	Well Count - All Exploratory	677	cb_2020_us_county_500k	GEOID	TOTAL_EXPL_WELL_CONUS_2020	ACTIVITY	USA	Well Count - All Exploratory
USA	Completions at Gas Wells	678	cb_2020_us_county_500k	GEOID	COMPLETIONS_GAS_CONUS_2020	ACTIVITY	USA	Completions at Gas Wells
USA	Completions at CBM Wells	679	cb_2020_us_county_500k	GEOID	COMPLETIONS_CBM_CONUS_2020	ACTIVITY	USA	Completions at CBM Wells
USA	Spud Count - Oil Wells	681	cb_2020_us_county_500k	GEOID	SPUD_OIL_CONUS_2020	ACTIVITY	USA	Spud Count - Oil Wells
USA	Produced Water at All Wells	683	cb_2020_us_county_500k	GEOID	PRODUCED_WATER_ALL_CONUS_2020	ACTIVITY	USA	Produced Water at All Wells
USA	Produced Water at CBM Wells	6831	cb_2020_us_county_500k	GEOID	PRODUCED_WATER_CBM_CONUS_2020	ACTIVITY	USA	Produced Water at CBM Wells
USA	Produced Water at Gas Wells	6832	cb_2020_us_county_500k	GEOID	PRODUCED_WATER_GAS_CONUS_2020	ACTIVITY	USA	Produced Water at Gas Wells
USA	Produced Water at Oil Wells	6833	cb_2020_us_county_500k	GEOID	PRODUCED_WATER_OIL_CONUS_2020	ACTIVITY	USA	Produced Water at Oil Wells
USA	Completions at Oil Wells	685	cb_2020_us_county_500k	GEOID	COMPLETIONS_OIL_CONUS_2020	ACTIVITY	USA	Completions at Oil Wells
USA	Completions at All Wells	686	cb_2020_us_county_500k	GEOID	COMPLETIONS_ALL_CONUS_2020	ACTIVITY	USA	Completions at All Wells

# Surrogate Definitions

REGION	SURROGATE	SURROGATE_CODE	DATA_SHAPEFILE	DATA_ATTRIBUTE	WEIGHT_SHAPEFILE	WEIGHT_ATTRIBUTE	WEIGHT_FUNCTION	FILTER_FUNCTION
USA	Feet Drilled at All Wells	687	cb_2020_us_county_500k	GEOID	FEET_DRILLED_CONUS_2020	ACTIVITY	USA	Feet Drilled at All Wells
USA	Gas Produced - Total	689	cb_2020_us_county_500k	GEOID	TOTAL_GAS_PRODUCTION_CONUS_2020	ACTIVITY	USA	Gas Produced - Total
USA	Well Counts - CBM Wells	691	cb_2020_us_county_500k	GEOID	CBM_WELLS_CONUS_2020	ACTIVITY	USA	Well Counts - CBM Wells
USA	Spud Count - All Wells	692	cb_2020_us_county_500k	GEOID	SPUD_ALL_CONUS_2020	ACTIVITY	USA	Spud Count - All Wells
USA	Well Count - All Wells	693	cb_2020_us_county_500k	GEOID	TOTAL_WELL_CONUS_2020	ACTIVITY	USA	Well Count - All Wells
USA	Oil Production at Oil Wells	694	cb_2020_us_county_500k	GEOID	OIL_PRODUCTION_CONUS_2020	ACTIVITY	USA	Oil Production at Oil Wells
USA	Well Count - Oil Wells	695	cb_2020_us_county_500k	GEOID	OIL_WELLS_CONUS_2020	ACTIVITY	USA	Well Count - Oil Wells
USA	Gas Production at Gas Wells	696	cb_2020_us_county_500k	GEOID	GAS_PRODUCTION_CONUS_2020	ACTIVITY	USA	Gas Production at Gas Wells
USA	Oil Production at Gas Wells	697	cb_2020_us_county_500k	GEOID	CONDENSATE_GAS_PRODUCTION_CONUS_2020	ACTIVITY	USA	Oil Production at Gas Wells
USA	Well Count - Gas Wells	698	cb_2020_us_county_500k	GEOID	GAS_WELLS_CONUS_2020	ACTIVITY	USA	Well Count - Gas Wells
USA	Gas Production at CBM Wells	699	cb_2020_us_county_500k	GEOID	CBM_PRODUCTION_CONUS_2020	ACTIVITY	USA	Gas Production at CBM Wells
USA	Airport Areas	711	cb_2020_us_county_500k	geoid	airport_area	area	USA	Airport Areas
USA	Port Areas	801	cb_2020_us_county_500k	geoid	Ports_2014NEI	area_sqmi	USA	Port Areas
USA	Golf Courses	850	cb_2020_us_county_500k	geoid	usa_golf_courses_2019_10	NONE	USA	Golf Courses
USA	Mines	860	cb_2020_us_county_500k	geoid	usgs_mrds_active_mines	NONE	USA	Mines



# Surrogate Definitions

REGION	SURROGATE	SURROGATE CODE	DATA SHAPEFILE	DATA ATTRIBUTE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE	WEIGHT FUNCTION	FILTER FUNCTION
USA	Sand and Gravel Mines	861	cb_2020_us_county_500k	geoid	usgs_mrds_active_mines	NONE	USA	Sand and Gravel Mines
USA	Lead Mines	862	cb_2020_us_county_500k	geoid	usgs_mrds_active_mines	NONE	USA	Lead Mines
USA	Crushed Stone Mines	863	cb_2020_us_county_500k	geoid	usgs_mrds_active_mines	NONE	USA	Crushed Stone Mines
USA	OSM Fuel	900	cb_2020_us_county_500k	geoid	osm_fuel_points_us_mar2023	NONE	USA	OSM Fuel
USA	OSM Asphalt Surfaces	901	cb_2020_us_county_500k	geoid	osm_asphalt_surfaces_us_mar2023	NONE	USA	OSM Asphalt Surfaces
USA	OSM Unpaved Roads	902	cb_2020_us_county_500k	geoid	osm_unpaved_roads_us_mar2023	NONE	USA	OSM Unpaved Roads

# Gapfilling Configuration

REGION	SURROGATE	SURROGATE CODE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
USA	Population	100			
USA	Housing	110	Population		
USA	Detached Housing	135	NLCD Low Intensity Development		
USA	Single and Dual Unit Housing	136	NLCD Low Intensity Development		
USA	Residential Heating - Natural Gas	150	Population		
USA	Residential Heating - Distillate Oil	170	Housing		
USA	Residential Heating - Coal	180	Housing		
USA	Residential Heating - LP Gas	190	Housing		
USA	Extended Idle Locations	205	Total Road Miles		
USA	Total Road AADT	239	Total Road Miles		
USA	Total Road Miles	240			
USA	All Restricted AADT	242	Total Road Miles		
USA	All Unrestricted AADT	244	Total Road Miles		
USA	Transit Bus Terminals	259	Population	NLCD Land	
USA	Total Railroad Miles	260	Total Road Miles	Population	
USA	NTAD Total Railroad Density	261	Total Railroad Miles	Total Road Miles	Population
USA	NTAD Class 1 2 3 Railroad Density	271	NTAD Total Railroad Density	Total Railroad Miles	Total Road Miles
USA	NLCD Low Intensity Development	300	Housing	Population	NLCD Land
USA	NLCD Open + Low	304	Housing	Population	NLCD Land
USA	NLCD Low + Med	305	Housing	Population	NLCD Land
USA	NLCD Med + High	306	Housing	Population	NLCD Land
USA	NLCD All Development	307	Housing	Population	NLCD Land
USA	NLCD Low + Med + High	308	Housing	Population	NLCD Land

# Gapfilling Configuration

REGION	SURROGATE	SURROGATE CODE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
USA	NLCD Open + Low + Med	309	Housing	Population	NLCD Land
USA	NLCD Total Agriculture	310	NLCD Open + Low	NLCD Land	
USA	NLCD Pasture Land	318	Housing	NLCD Land	
USA	NLCD Crop Land	319	Housing	NLCD Land	
USA	NLCD Forest Land	320	Housing	NLCD Land	
USA	NLCD Recreational Land	321	Housing	NLCD Land	
USA	NLCD Land	340			
USA	NLCD Water	350			
USA	FAO 2010 Cattle	401	NLCD Total Agriculture	NLCD Open + Low	
USA	FAO 2010 Large Cattle Operations	4011	FAO 2010 Cattle	NLCD Total Agriculture	NLCD Open + Low
USA	NPDES 2020 Beef Cattle	4012	FAO 2010 Cattle	NLCD Total Agriculture	NLCD Open + Low
USA	NPDES 2020 Dairy Cattle	4013	FAO 2010 Large Cattle Operations	NLCD Total Agriculture	NLCD Open + Low
USA	FAO 2010 Pig	402	NLCD Total Agriculture	NLCD Open + Low	
USA	NPDES 2020 Swine	4021	FAO 2010 Pig	NLCD Total Agriculture	NLCD Open + Low
USA	FAO 2010 Chicken	403	NLCD Total Agriculture	NLCD Open + Low	
USA	NPDES 2020 Chicken	4031	FAO 2010 Chicken	NLCD Total Agriculture	NLCD Open + Low
USA	FAO 2010 Goat	404	NLCD Total Agriculture	NLCD Open + Low	
USA	NPDES 2020 Goat	4041	FAO 2010 Goat	NLCD Total Agriculture	NLCD Open + Low
USA	FAO 2010 Horse	405	NLCD Total Agriculture	NLCD Open + Low	
USA	FAO 2010 Sheep	406	NLCD Total Agriculture	NLCD Open + Low	
USA	NPDES 2020 Turkey	4071	NLCD Total Agriculture	NLCD Open + Low	
USA	Refineries and Tank Farms	650	NLCD Low + Med	Population	NLCD Land
USA	Spud Count - CBM Wells	670	Spud Count - All Wells	Well Count - All Wells	

# Gapfilling Configuration

REGION	SURROGATE	SURROGATE CODE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
USA	Spud Count - Gas Wells	671	Well Count - Gas Wells	Well Count - All Wells	
USA	Gas Production at Oil Wells	672	NLCD Open + Low	Well Count - Oil Wells	Well Count - All Wells
USA	Oil Production at CBM Wells	673	Well Count - CBM Wells	Well Count - All Wells	NLCD Open + Low
USA	Unconventional Well Completion Counts	674	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
USA	Well Count - All Producing	676	Well Count - All Wells	NLCD Open + Low	
USA	Well Count - All Exploratory	677	Well Count - All Wells	NLCD Open + Low	
USA	Completions at Gas Wells	678	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low
USA	Completions at CBM Wells	679	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low
USA	Spud Count - Oil Wells	681	Well Count - Oil Wells	Well Count - All Wells	NLCD Open + Low
USA	Produced Water at All Wells	683	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
USA	Produced Water at CBM Wells	6831	Well Counts - CBM Wells	Well Count - All Wells	NLCD Open + Low
USA	Produced Water at Gas Wells	6832	Well Count - Gas Wells	Well Count - All Wells	NLCD Open + Low
USA	Produced Water at Oil Wells	6833	Well Count - Oil Wells	Well Count - All Wells	NLCD Open + Low
USA	Completions at Oil Wells	685	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low
USA	Completions at All Wells	686	Well Count - All Exploratory	Well Count - All Wells	NLCD Open + Low
USA	Feet Drilled at All Wells	687	Well Count - All Exploratory	Well Count - All Wells	NLCD Open + Low
USA	Gas Produced - Total	689	Well Count - All Wells	NLCD Open + Low	
USA	Well Counts - CBM Wells	691	Completions at CBM Wells	Well Count - All Wells	NLCD Open + Low
USA	Spud Count - All Wells	692	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
USA	Well Count - All Wells	693	NLCD Open + Low		
USA	Oil Production at Oil Wells	694	Completions at Oil Wells	Well Count - All Wells	NLCD Open + Low
USA	Well Count - Oil Wells	695	Completions at Oil Wells	Well Count - All Wells	NLCD Open + Low
USA	Gas Production at Gas Wells	696	Completions at Gas Wells	Well Count - All Wells	NLCD Open + Low



# Gapfilling Configuration

REGION	SURROGATE	SURROGATE CODE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
USA	Oil Production at Gas Wells	697	Well Count - Gas Wells	Well Count - All Wells	NLCD Open + Low
USA	Well Count - Gas Wells	698	Completions at Gas Wells	Well Count - All Wells	NLCD Open + Low
USA	Gas Production at CBM Wells	699	Well Counts - CBM Wells	Well Count - All Wells	NLCD Open + Low
USA	Airport Areas	711	Population	NLCD Land	
USA	Port Areas	801	NLCD Water		
USA	Golf Courses	850	Housing	Population	NLCD Land
USA	Mines	860	NLCD Open + Low	NLCD Land	
USA	Sand and Gravel Mines	861	Mines	NLCD Open + Low	NLCD Land
USA	Lead Mines	862	Mines	NLCD Open + Low	NLCD Land
USA	Crushed Stone Mines	863	Mines	NLCD Open + Low	NLCD Land
USA	OSM Fuel	900	Total Road AADT	Total Road Miles	
USA	OSM Asphalt Surfaces	901	NLCD All Development		
USA	OSM Unpaved Roads	902	NLCD Open + Low		