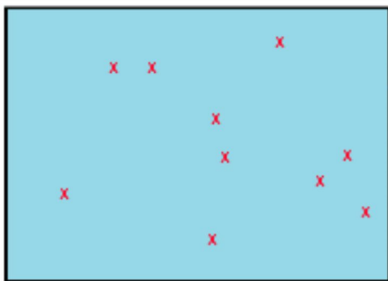


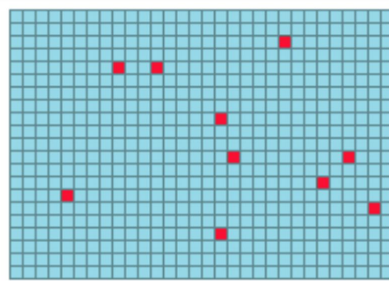
raster data

foundations of geospatial analysis

2026.10.19



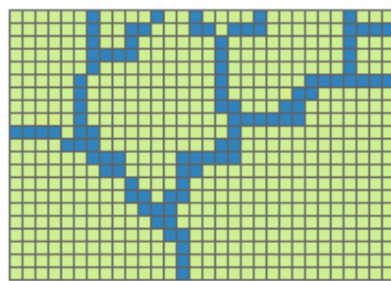
Point features



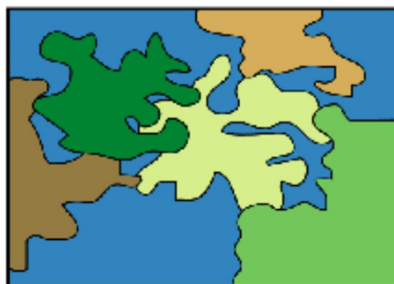
Raster point features



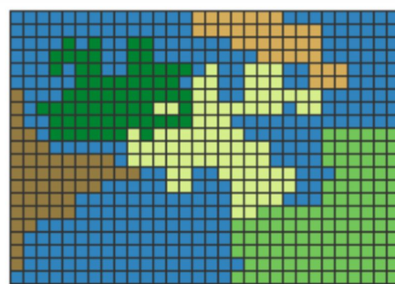
Line features



Raster line features



Polygon features



Raster polygon features

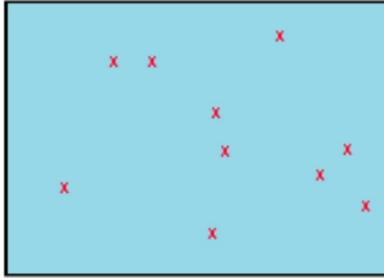
vector data

computed geometries

point, line, and polygon
are different models

relationally displayed

quite complex to spatially
process - e.g., how does
the computer know
whether two polygons
touch?



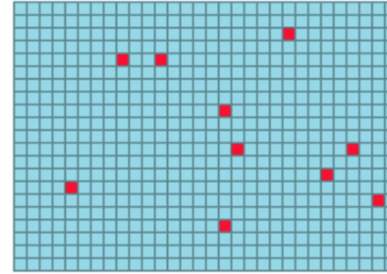
Point features



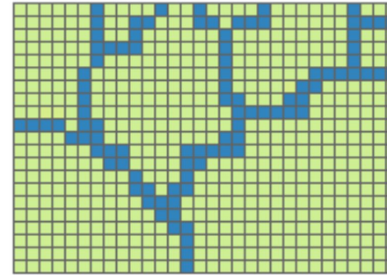
Line features



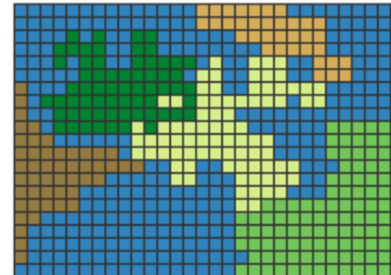
Polygon features



Raster point features



Raster line features



Raster polygon features

raster data

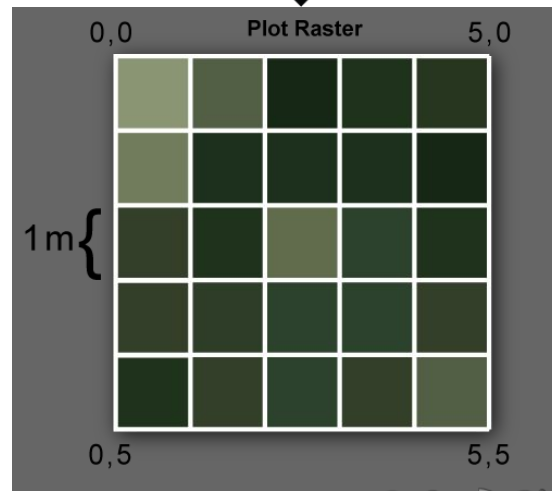
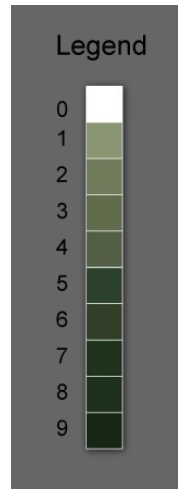
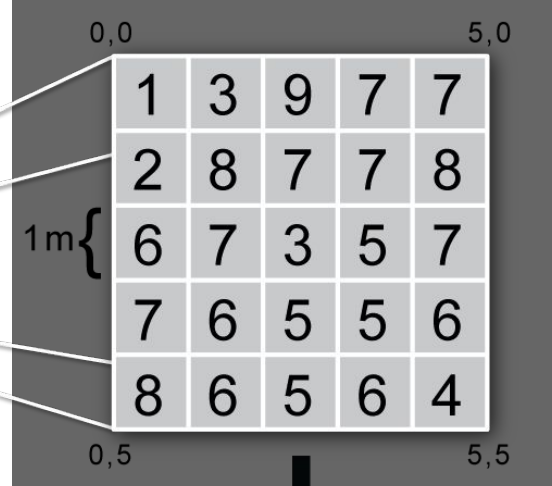
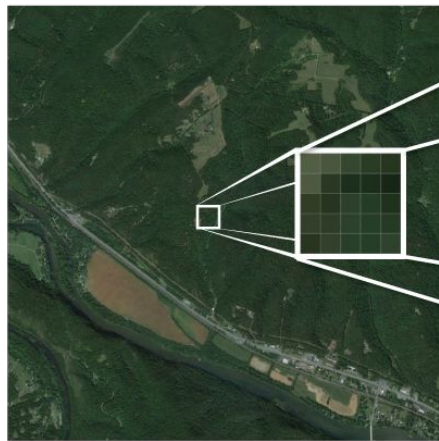
gridded values

point, line, and polygon
are not different models

not relationally
displayed

sort of easy to spatially
process - e.g., how does
the computer know
whether two pixels in a
grid touch?

rasters are
big grids
made of
pixels



pixels **are the
fundamental
building block of
the raster data
model**

A Brief History of ‘Pixel’

Richard F. Lyon

Foveon Inc., 2820 San Tomas Expressway, Santa Clara CA 95051

A Brief History of ‘Pixel’

Richard F. Lyon

Foveon Inc., 2820 San Tomas Expressway, Santa Clara CA 95051

*“a succession of **little areas** of
varying brilliance”*

*“a mosaic of **selenium cells**”*

*“a **great number of small parts,**
thousands of little squares”*

A Brief History of ‘Pixel’

Richard F. Lyon

Foveon Inc., 2820 San Tomas Expressway, Santa Clara CA 95051

As computerized scanning, processing, and reproduction of images were being explored in the 1950s^{17,18} and 1960s, *picture element* was seldom used in these fields, with a few exceptions such as Schreiber,¹⁹ Roberts,²⁰ and Seyler.²¹ For example, in the 1968 collection *Pictorial Pattern Recognition*,²² we find *resolution elements*, *positions*, *spots*, *sample spots*, *samples*, *gray values*, *raster points*, *matrix elements*, *video element*, *point*, *digital sample*, *beam spot*, *digital-picture element*, and, yes, even *picture element*. These don’t show any more consistency than terms used in the 1920s, which included *image element*, *area element*, *elementary area*, *picture units*, *small squares*, *little parts*, *units*, *dots*, *points*, *discrete signals*, *portions*, *elemental area of the picture*, and *elemental tone value*.

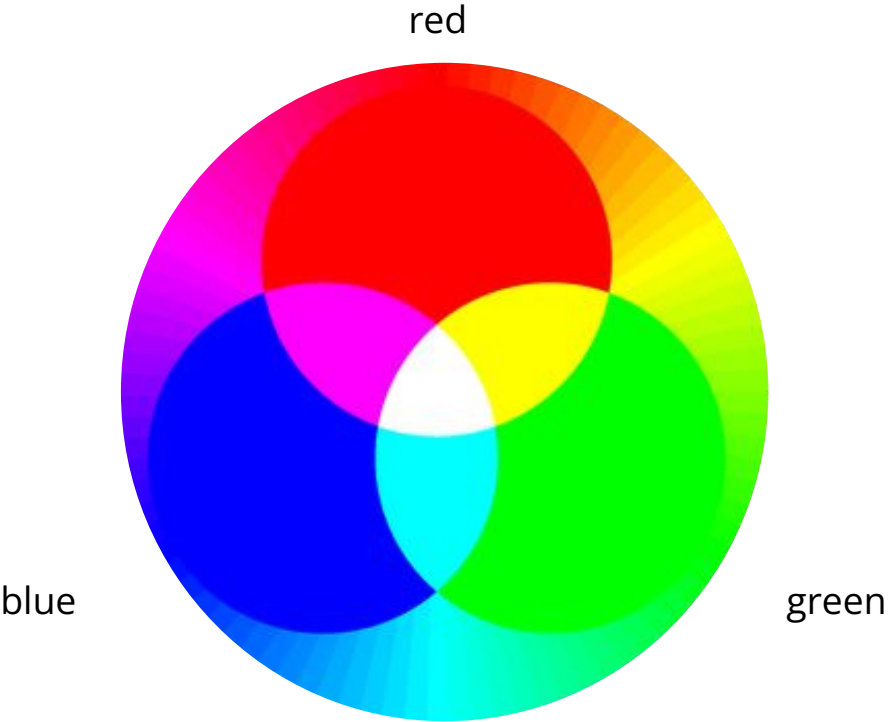
**pixel = “picture
element”**

bit depth **describes
the range of
values that a
raster file can
store**

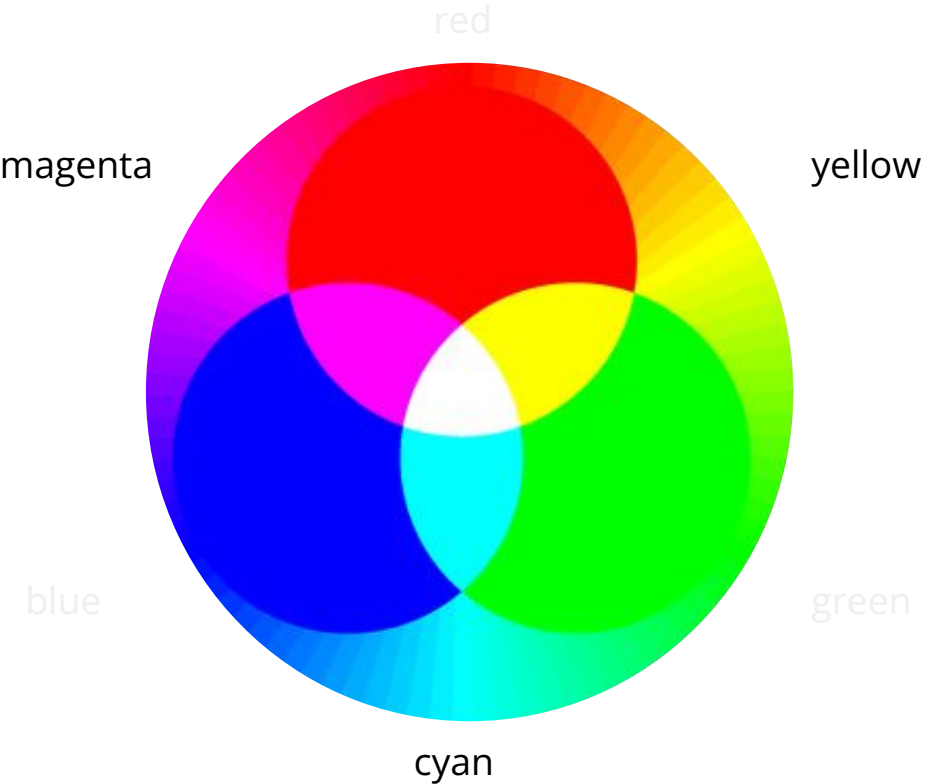
**e.g., each pixel in
an *8-bit* raster can
have 256 values,
from 0-255**

**these values refer
to the brightness
of a color**

for screens...



for print...



**bit depth ranges
from 1-bit to
64-bit**

Bit depth

Range of values that each cell can contain

1 bit	0 to 1	 <i>small file size</i>
2 bit	0 to 3	
4 bit	0 to 15	
Unsigned 8 bit	0 to 255	
Signed 8 bit	-128 to 127	 <i>big file size</i>
Unsigned 16 bit	0 to 65535	
Signed 16 bit	-32768 to 32767	
Unsigned 32 bit	0 to 4294967295	
Signed 32 bit	-2147483648 to 2147483647	
Floating-point 32 bit	-3.402823466e+38 to 3.402823466e+38	
Unsigned 64 bit	0 to 18446744073709551616	

Bit depth

Range of values that each cell can contain

1 bit

0 to 1

2 bit

0 to 3

4 bit

0 to 15

Unsigned 8 bit

0 to 255

Signed 8 bit

-128 to 127

Unsigned 16 bit

0 to 65535

Signed 16 bit

-32768 to 32767

Unsigned 32 bit

0 to 4294967295

Signed 32 bit

-2147483648 to 2147483647

Floating-point 32 bit

-3.402823466e+38 to 3.402823466e+38

Unsigned 64 bit

0 to 18446744073709551616

you'll commonly
encounter 8-bit rasters

*small
file
size*

*big
file
size*

Bit depth

Range of values that each cell can contain

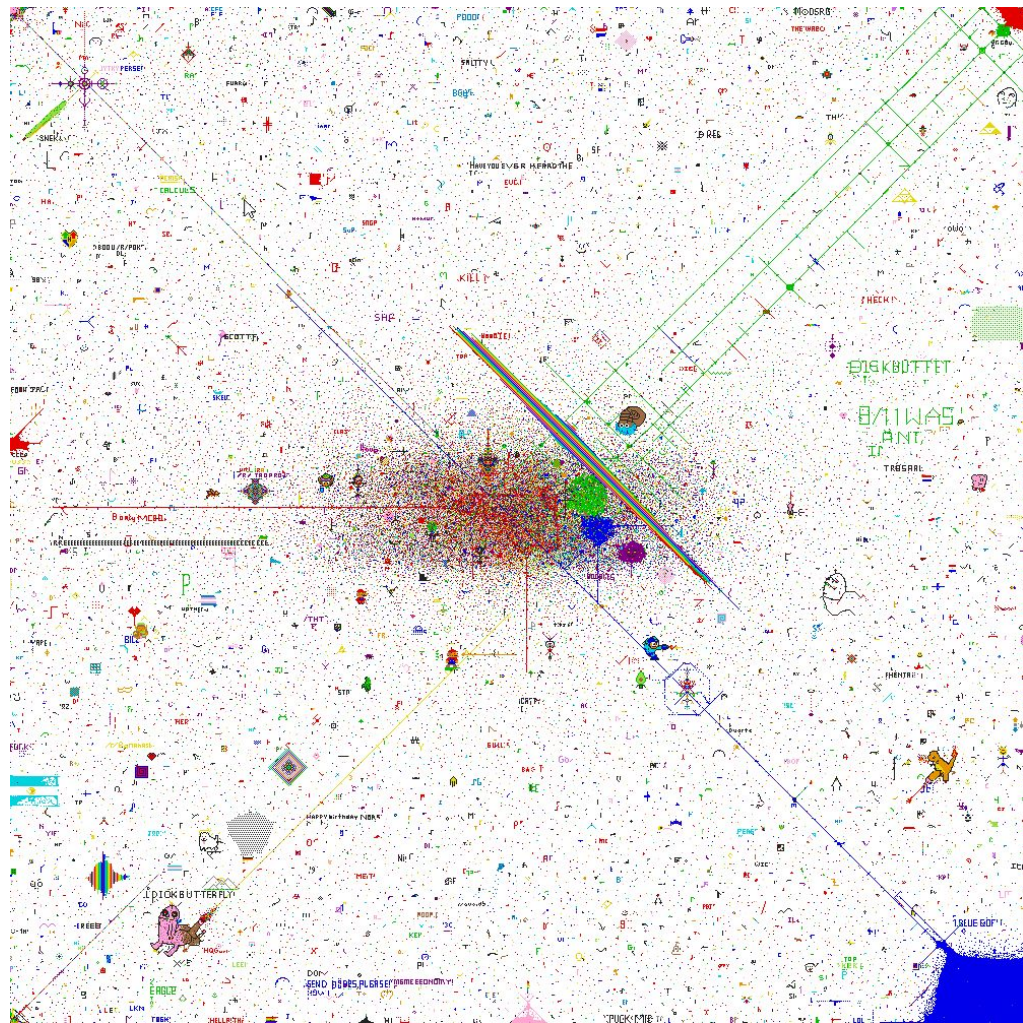
1 bit	0 to 1
2 bit	0 to 3
4 bit	0 to 15
Unsigned 8 bit	0 to 255
Signed 8 bit	-128 to 127
Unsigned 16 bit	0 to 65535
Signed 16 bit	-32768 to 32767
Unsigned 32 bit	0 to 4294967295
Signed 32 bit	-2147483648 to 2147483647
Floating-point 32 bit	-3.402823466e+38 to 3.402823466e+38
Unsigned 64 bit	0 to 18446744073709551616

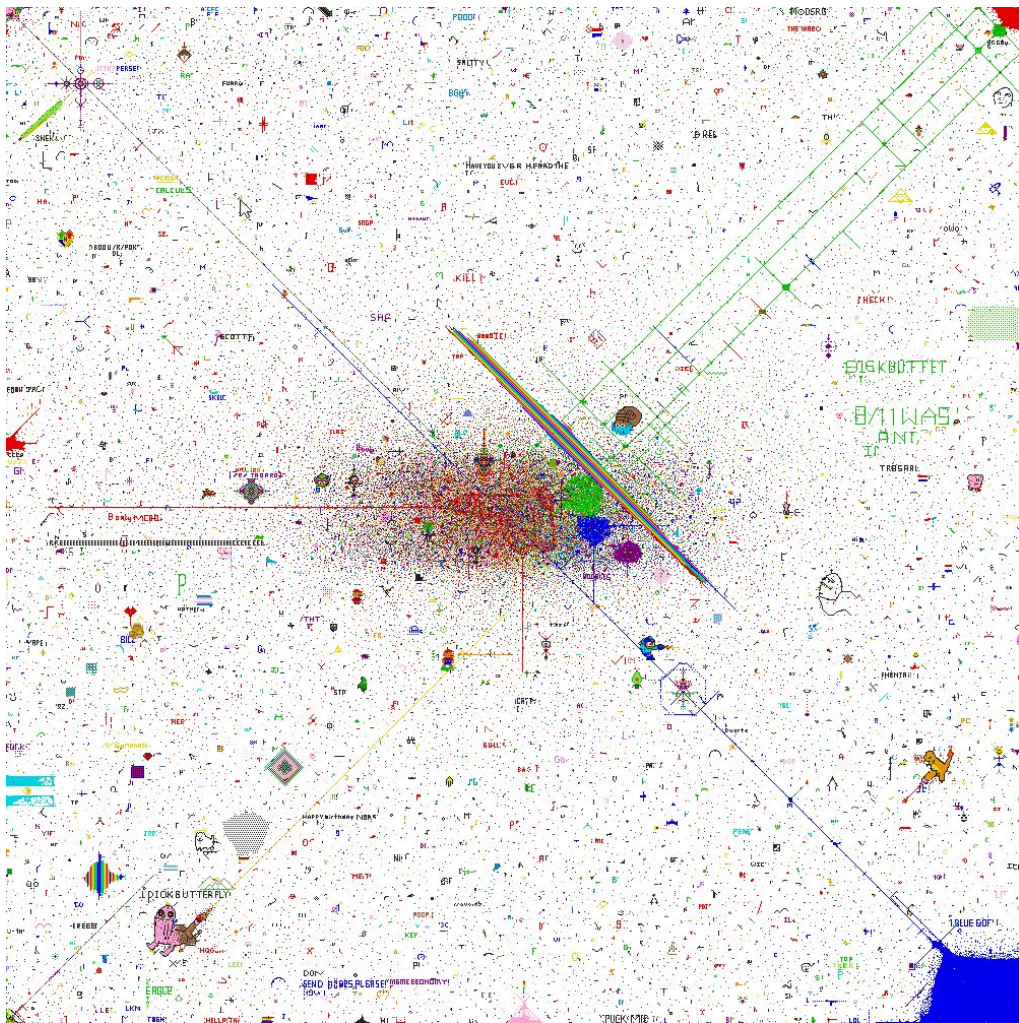
you will not commonly
encounter 64-bit rasters

*small
file
size*

*big
file
size*

**but pixels are
more than just
value ranges**



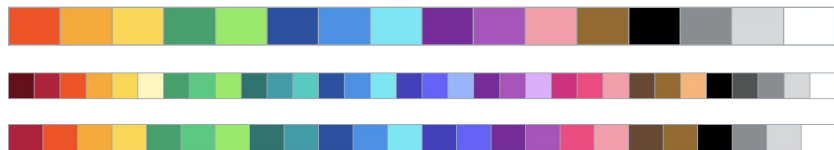


r/place, 2017



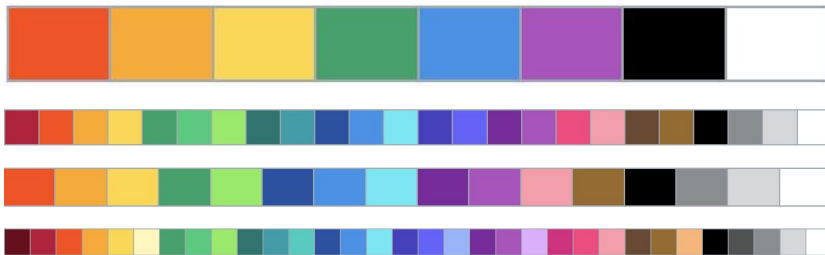


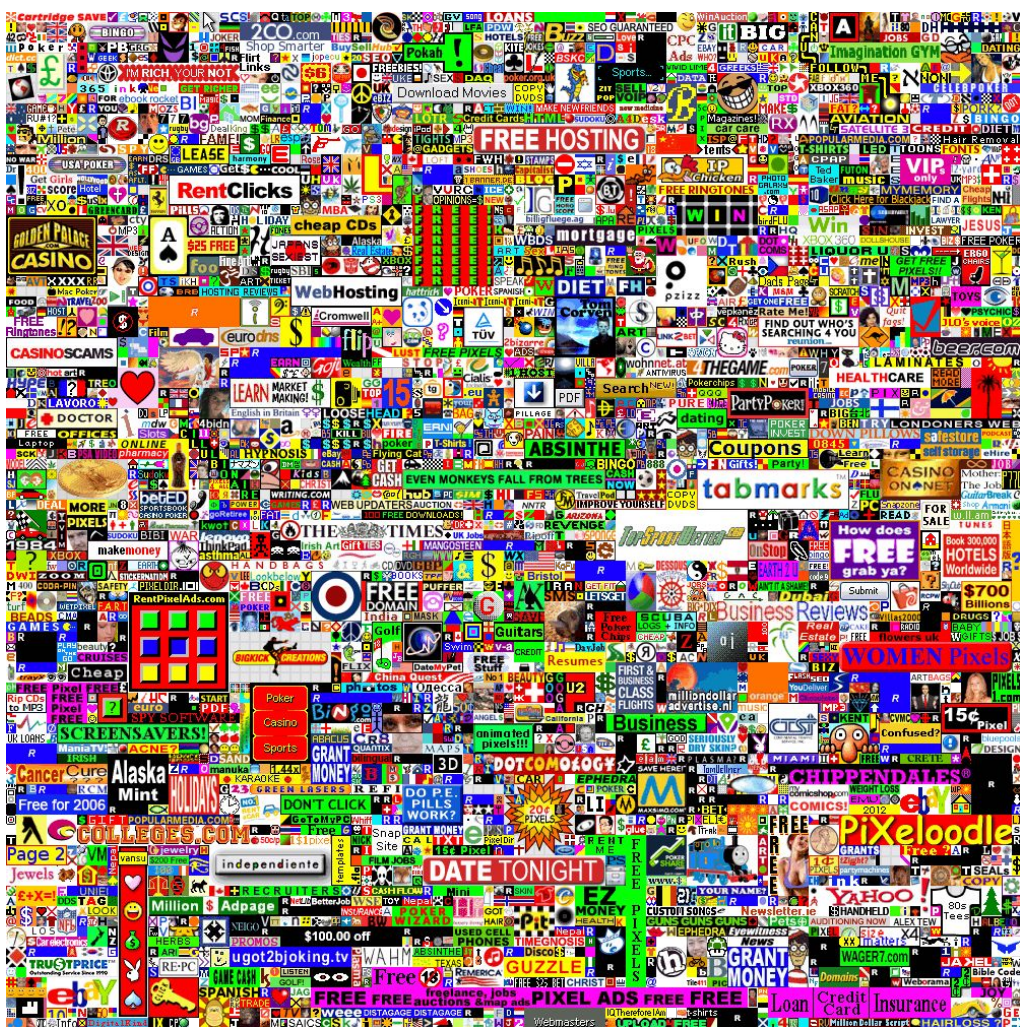
r/place, 2022

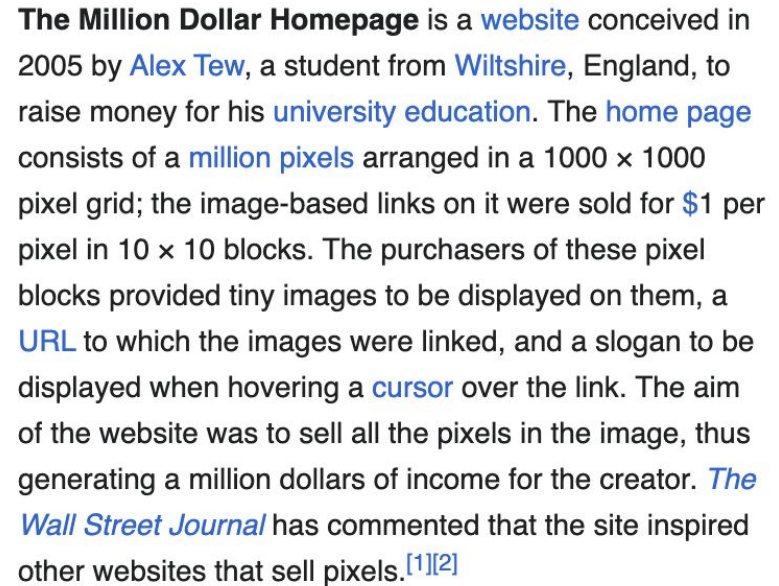


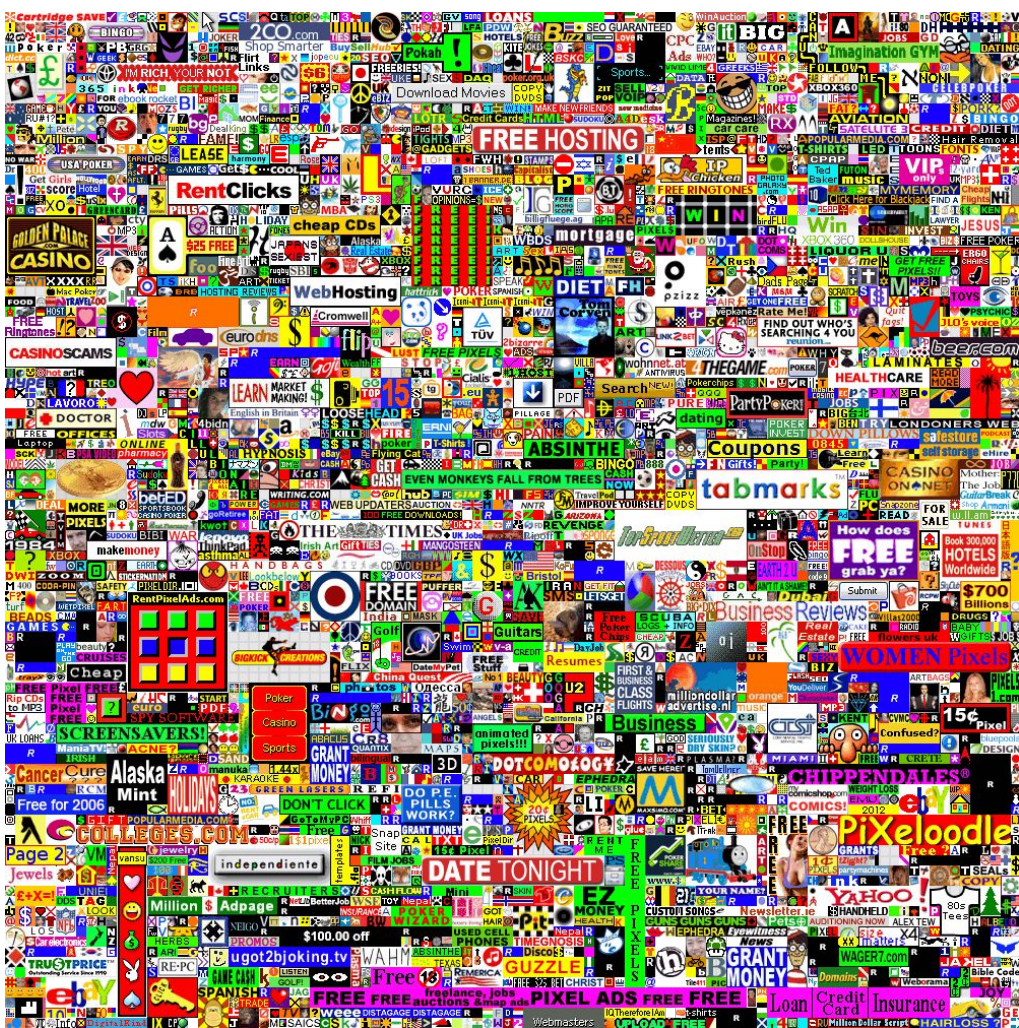


r/place, 2023









pixel as
internet real
estate?

pixel as
commodity?

Artists Can Use This Tool to Protect Their Work From A.I. Scraping

Nightshade subtly alters the pixels of an image to mislead A.I. image generators, ultimately damaging the models



Teresa Nowakowski

Daily Correspondent

November 3, 2023

As artificial intelligence image generators become more popular and powerful, artists worry that their work will be used without permission to train tools like DALL-E, Midjourney, and Stable Diffusion.

Now, researchers at the University of Chicago have developed a technique that artists can use to embed invisible “poison” in their work, reports MIT Technology Review's Melissa Heikkilä. The tool, called Nightshade, changes an image's pixels in a way that humans can't detect.

Computers, however, will notice these changes, which are carefully designed to impair A.I. models' ability to label their images. If an A.I. model is trained on these kinds of images, its abilities will begin to break down. It will learn, for example, that cars are cows, or that cartoon art is Impressionism.

“This way, to a human or simple automated check, the image and the text seem aligned,” writes Ars Technica's Benj Edwards. “But in the model's latent space, the image has characteristics of both the original and the poison concept, which leads the model astray when trained on the data.”

pixel as...
poison??

A dense, colorful collage of various internet advertisements and logos. The collage is composed of numerous small, overlapping rectangular and square tiles, each containing a different type of advertisement. Prominent text includes 'FREE HOSTING', 'tabmarks', 'DATE TONIGHT', 'PIXELODDIE', 'FREE', 'HOTELS', 'FREE', 'DATE TONIGHT', 'PIXELODDIE', 'FREE', 'HOTELS', 'FREE', 'DATE TONIGHT', 'PIXELODDIE'. Other visible text includes 'RentClicks', 'WebHosting', 'DIET PLAN', 'tabmarks', 'FREE', 'HOTELS', 'FREE', 'DATE TONIGHT', 'PIXELODDIE'. The background is a mix of various colors and patterns, creating a busy and visually stimulating effect.

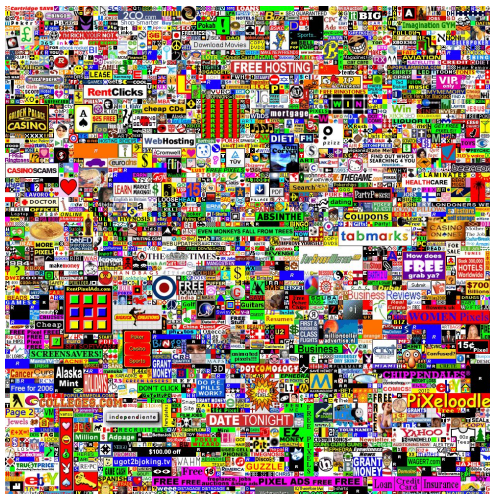


???



???

million
dollar
homepage

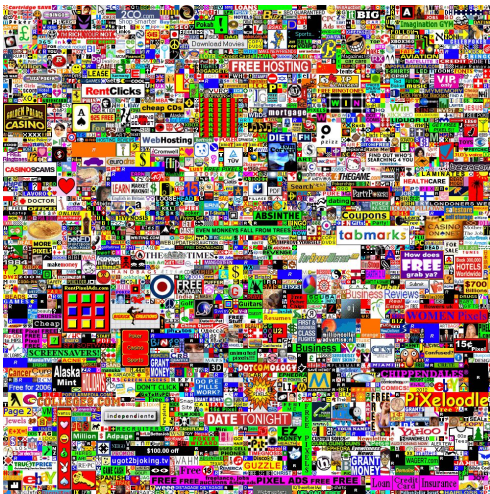


r/place

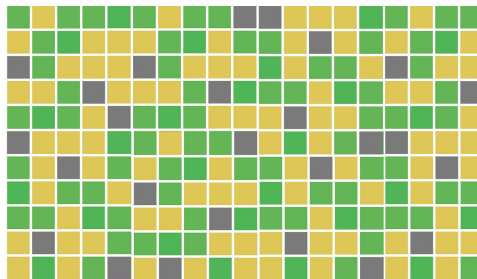


???

million
dollar
homepage



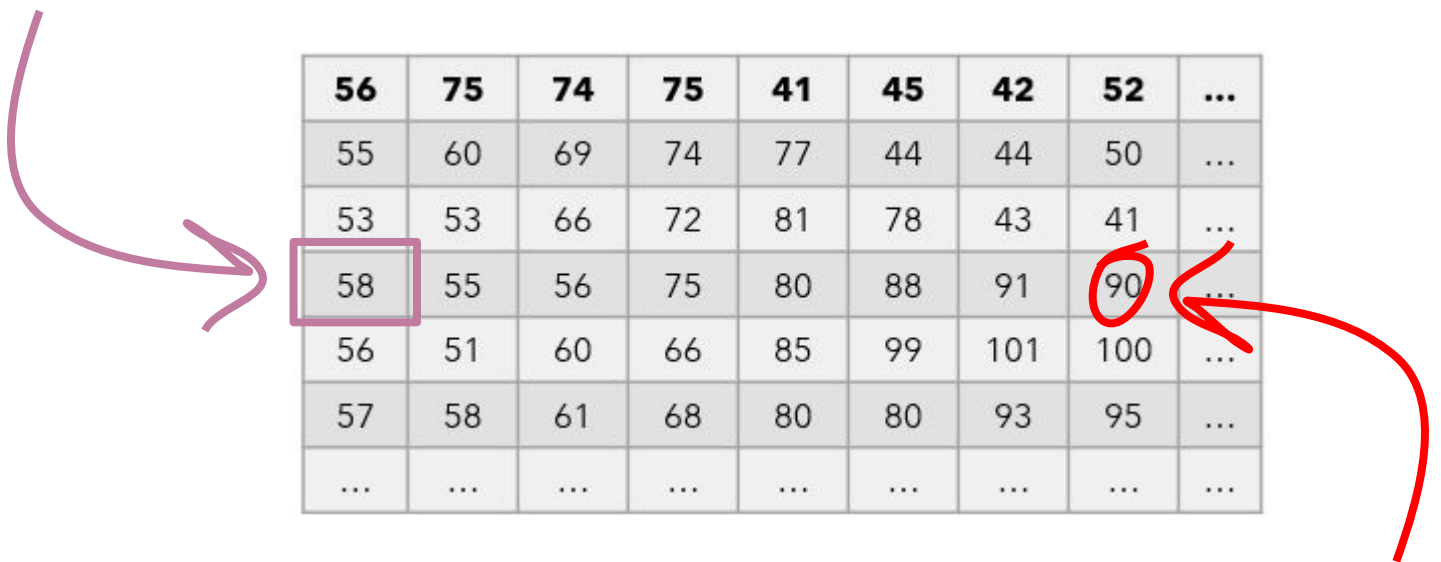
r/place



in gis, pixels have
two properties

geometric
and
radiometric

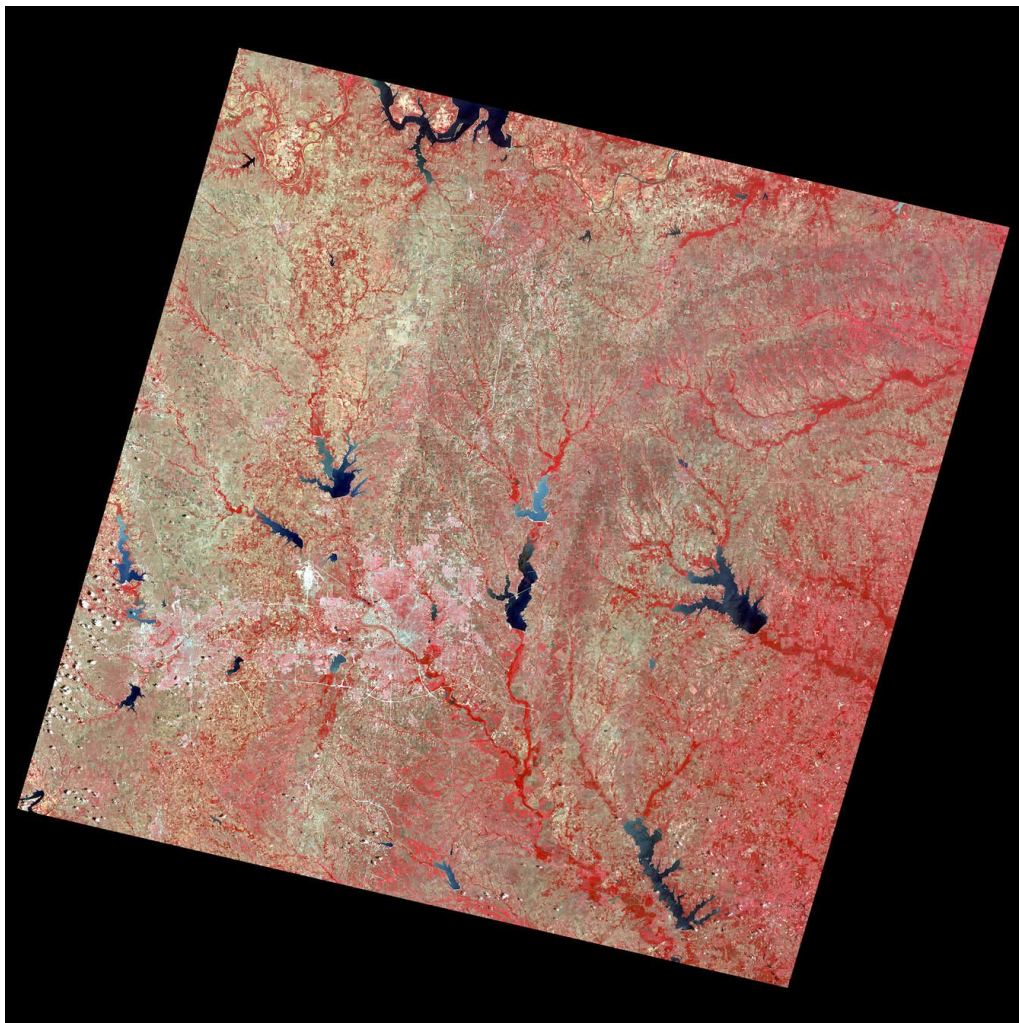
the **placement** of a pixel represents its **geometric** (e.g., spatial) property

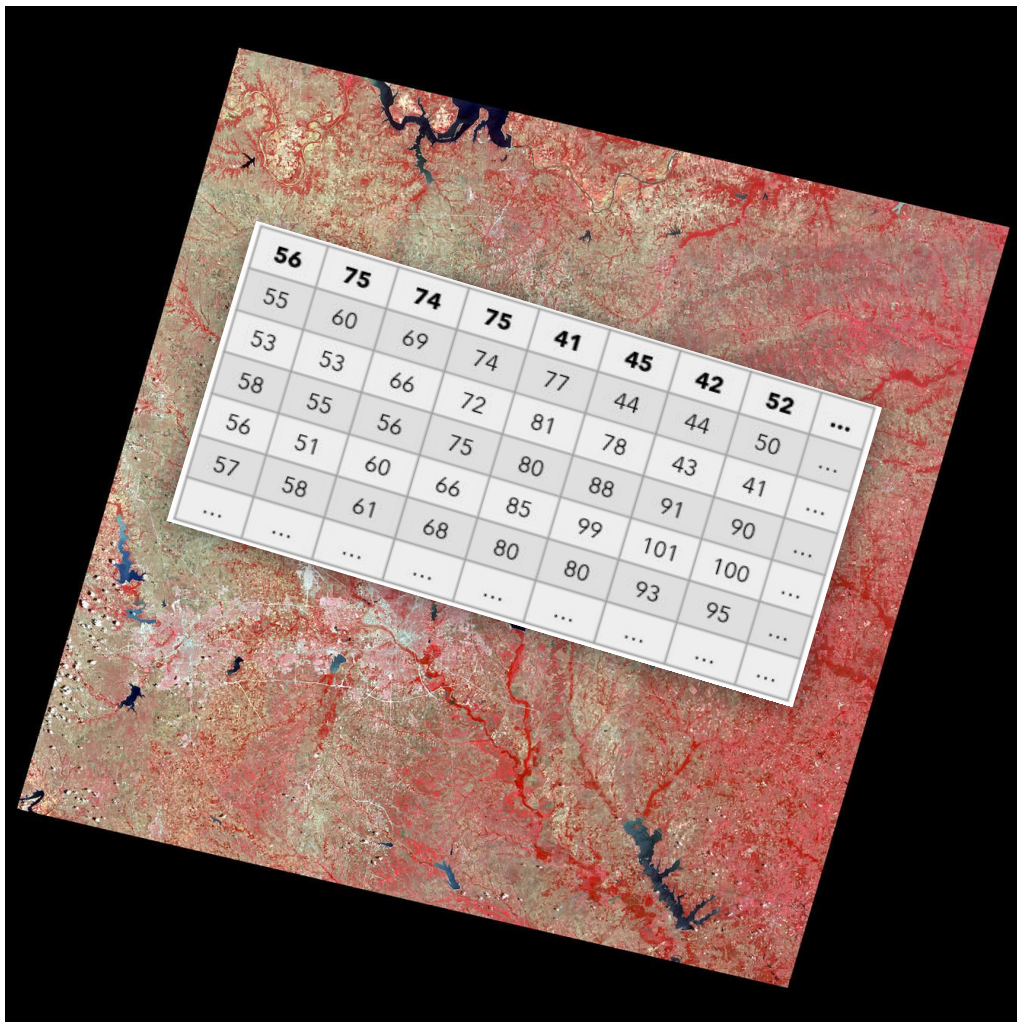


56	75	74	75	41	45	42	52	...
55	60	69	74	77	44	44	50	...
53	53	66	72	81	78	43	41	...
58	55	56	75	80	88	91	90	...
56	51	60	66	85	99	101	100	...
57	58	61	68	80	80	93	95	...
...	...	...	...	...	...	...	...	...

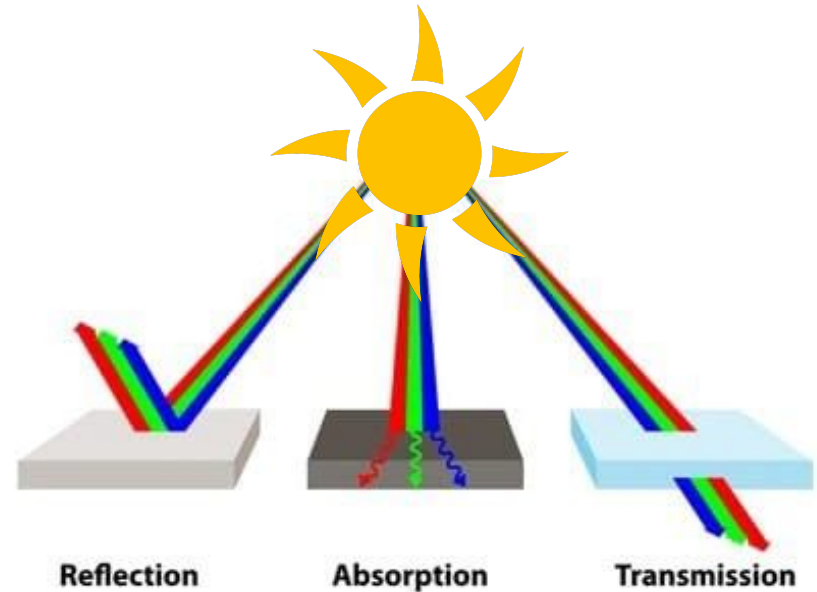
the **value** of a pixel represents its **radiometric** (e.g., brightness) property

**what's an
example of raster
data?**

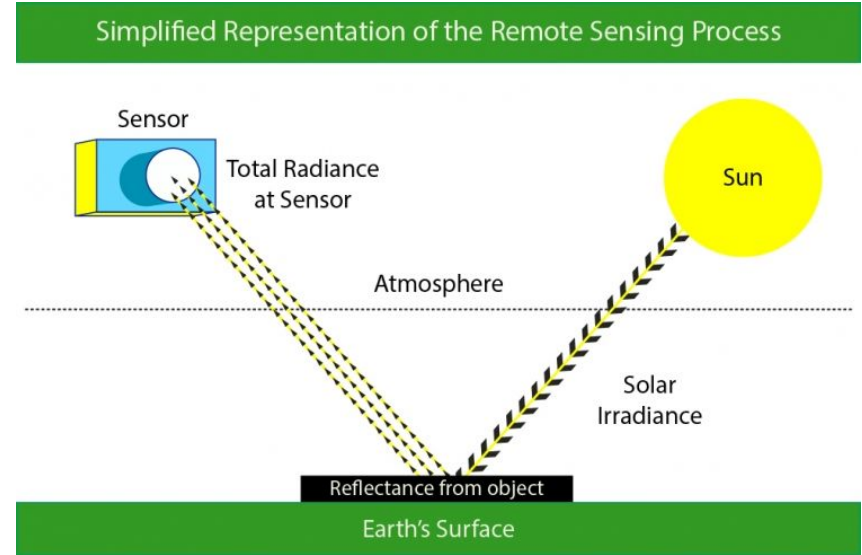




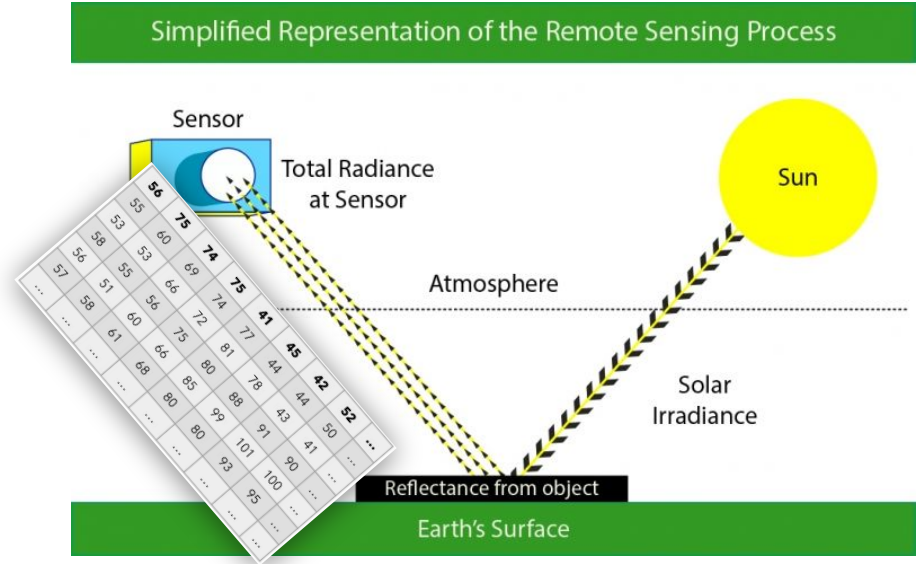
**photons emit
from the sun and
are either
reflected, absorbed,
or transmitted by
**the surfaces
they strike****

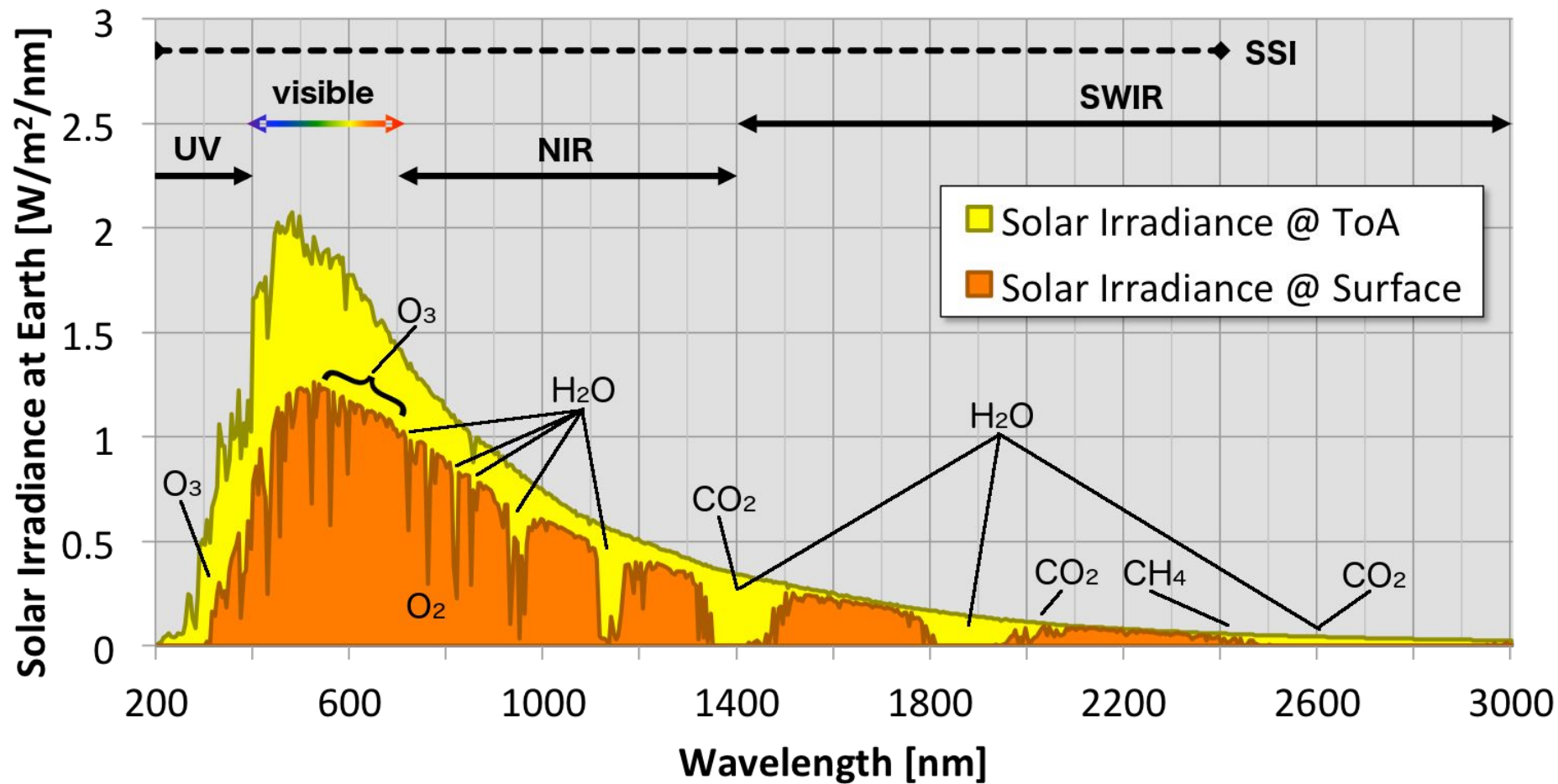


**“remote
sensing”
technology (e.g.,
satellites)
capture the
residual
irradiance, or
*reflectance***



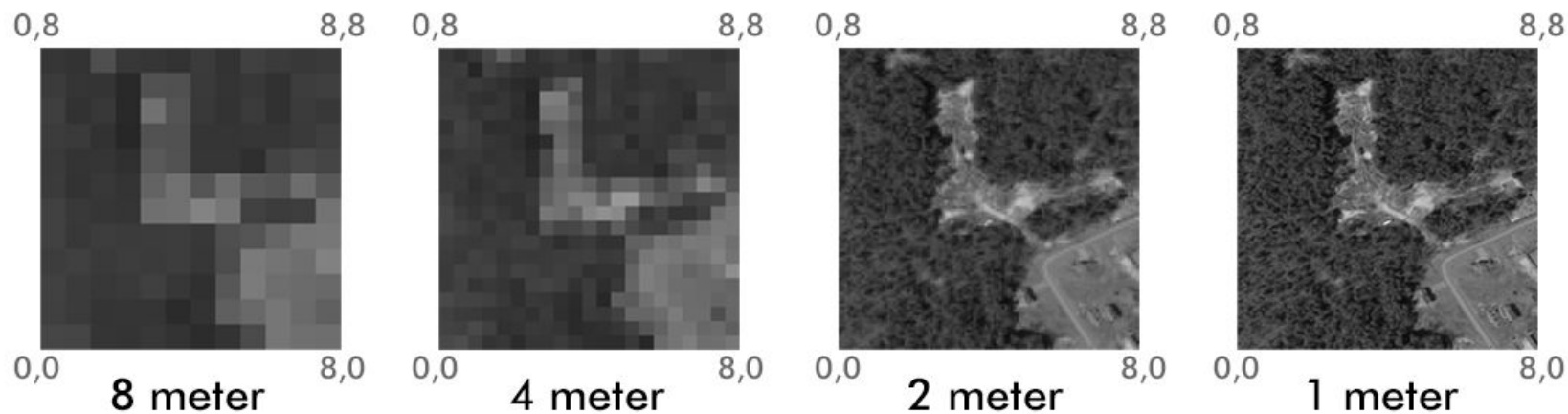
**which is what we
capture, encode,
and process as
*raster data***



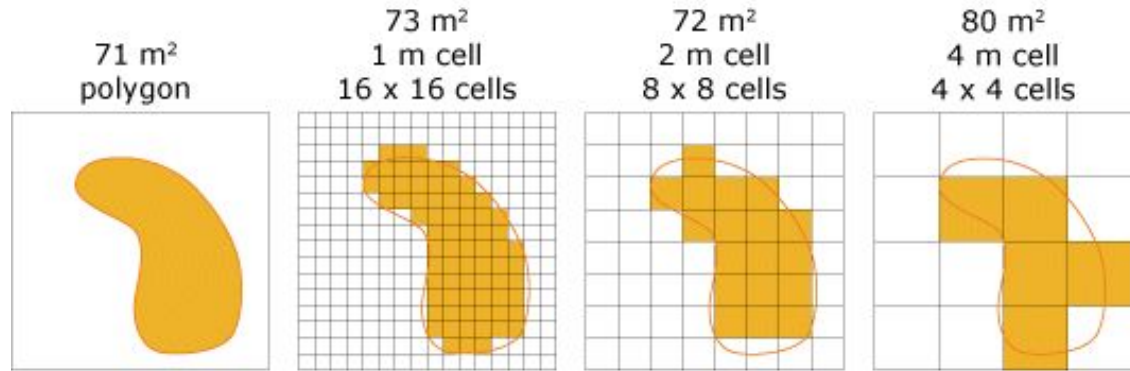


**in geospatial
analysis, *pixel size*
corresponds to
*geographic area***

Raster over the same extent, at 4 different resolutions



"raster = faster, vector = correcter"



- Smaller cell size
- Higher resolution
- Higher feature spatial accuracy
- Slower display
- Slower processing
- Larger file size

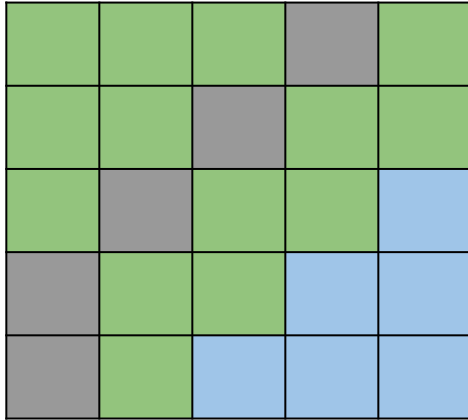
- Larger cell size
- Lower resolution
- Lower feature spatial accuracy
- Faster display
- Faster processing
- Smaller file size

**similar to vector data,
raster data can be
sorted into two kinds**

discrete **and** *continuous*

discrete rasters

what you see



what computer sees

1	1	1	2	1
1	1	2	1	1
1	2	1	1	3
2	1	1	3	3
2	1	3	3	3

discrete rasters

discrete rasters are
***processed, single-band
images*** in which the value
of each cell (or pixel)
corresponds to a category
or type

this is similar to categorical
or qualitative data in
vectors

1	1	1	2	1
1	1	2	1	1
1	2	1	1	3
2	1	1	3	3
2	1	3	3	3

in the “raster” to the left, imagine:

1 = grass
2 = concrete
3 = water

the computer doesn’t know that 1
= grass... we have to tell it

discrete rasters

discrete rasters are
***processed, single-band
images*** in which the value
of each cell (or pixel)
corresponds to a category
or type

this is similar to categorical
or qualitative data in
vectors

1	1	1	2	1
1	1	2	1	1
1	2	1	1	3
2	1	1	3	3
2	1	3	3	3

using a gis, you could use
symbolology to classify these
appropriately

you want to use a *categorical
scheme*

discrete rasters

discrete rasters are ***processed, single-band images*** in which the value of each cell (or pixel) corresponds to a category or type

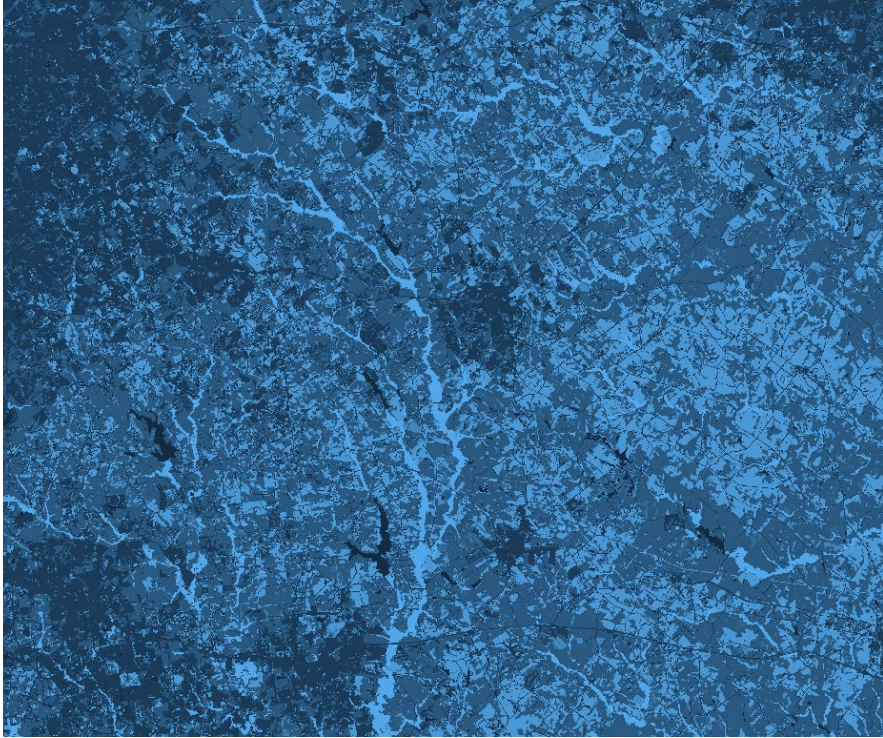
this is similar to categorical or qualitative data in vectors

1	1	1	2	1
1	1	2	1	1
1	2	1	1	3
2	1	1	3	3
2	1	3	3	3

examples of discrete rasters include

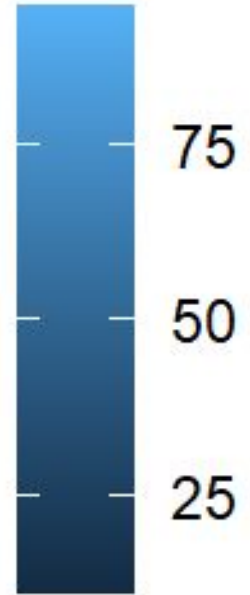
- measurements of land use
- vegetation and soil types
- suitability analysis (e.g., "most suitable for x," "least suitable for x")

discrete rasters

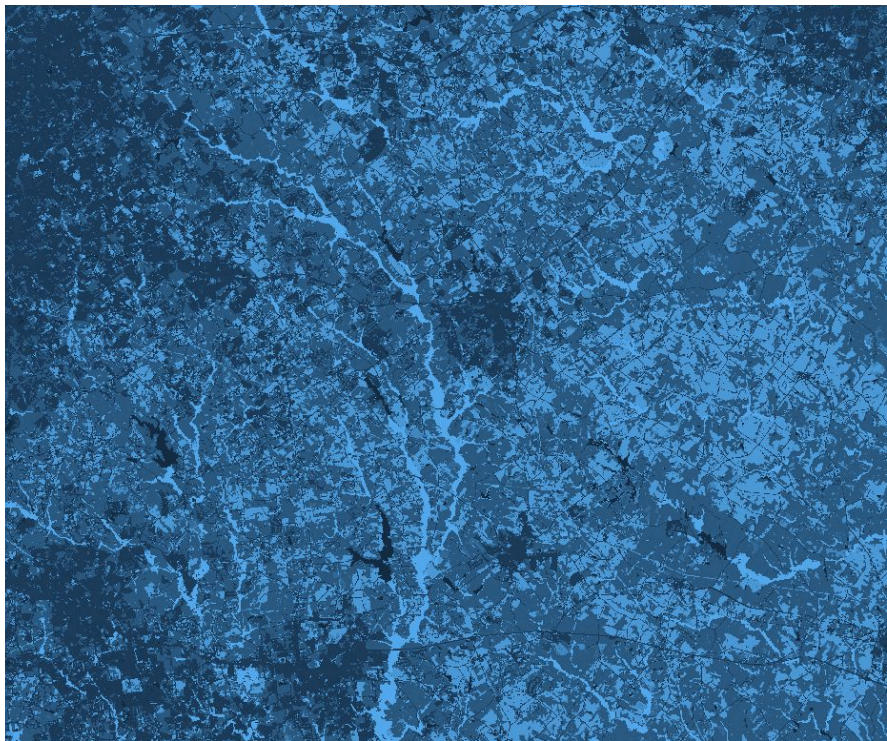


here's an example of
a land use raster,
stretched across a
single-band color
scheme

not ideal for
understanding the
discrete categories



discrete rasters



the Multi-Resolution
Land Characteristics
Consortium created
the data and
identified these
discrete categories

NLCD Land Cover Classification Legend

11	Open Water
12	Perennial Ice/ Snow
21	Developed, Open Space
22	Developed, Low Intensity
23	Developed, Medium Intensity
24	Developed, High Intensity
31	Barren Land (Rock/Sand/Clay)
41	Deciduous Forest
42	Evergreen Forest
43	Mixed Forest
51	Dwarf Scrub*
52	Shrub/Scrub
71	Grassland/Herbaceous
72	Sedge/Herbaceous*
73	Lichens*
74	Moss*
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

* Alaska only

discrete rasters



reclassifying it with a
meaningful color
ramp makes it much
easier to interpret

because the
different color hues
correspond to
discrete categories

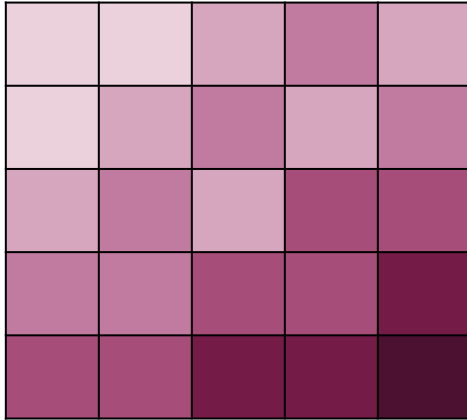
NLCD Land Cover Classification Legend

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72	Sedge/Herbaceous*
73	Lichens*
74	Moss*
81	Pasture/Hay
82	Cultivated Crops
90	Woody Wetlands
95	Emergent Herbaceous Wetlands

* Alaska only

continuous rasters

what you see



what computer sees

0	0	1	2	1
0	1	2	1	2
1	2	1	3	3
2	2	3	3	4
3	3	4	4	5

continuous rasters

continuous rasters are
remotely sensed values
from an ***emitted source***

e.g., from transmittance of
light or lasers

this is similar to numerical
or quantitative vector data

0	0	1	2	1
0	1	2	1	2
1	2	1	3	3
2	2	3	3	4
3	3	4	4	5

in the “raster” to the left:

- 0 = zero feet elevation
- 1 = one feet elevation
- 2 = two feet elevation
- 3 = three feet elevation
- 4 = four feet elevation
- 5 = five feet elevation

continuous rasters

continuous rasters are
remotely sensed values
from an ***emitted source***

e.g., from transmittance of
light or lasers

this is similar to numerical
or quantitative vector data

0	0	1	2	1
0	1	2	1	2
1	2	1	3	3
2	2	3	3	4
3	3	4	4	5

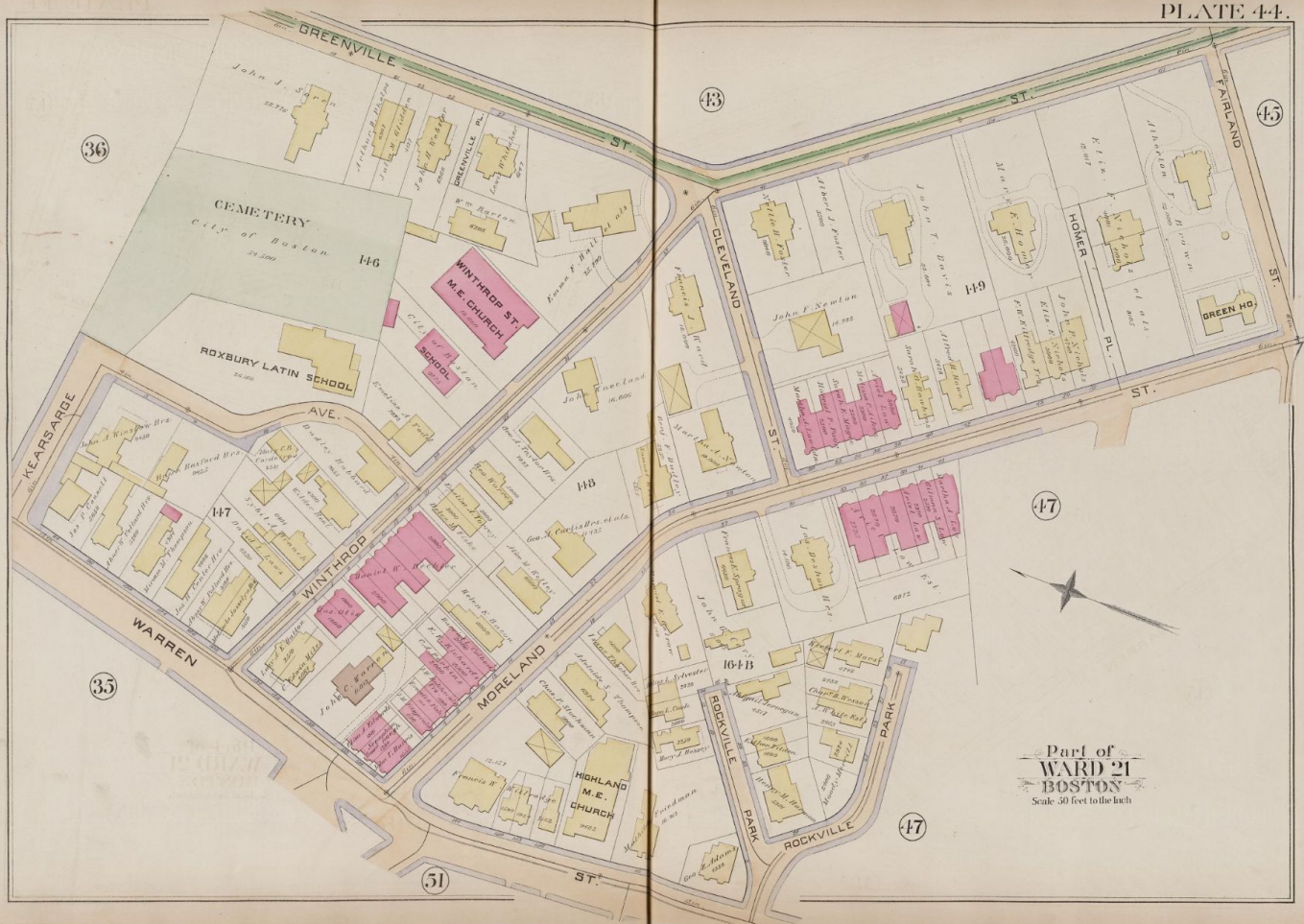
these digital elevation models - or
DEMs - are ideal at high bit depth

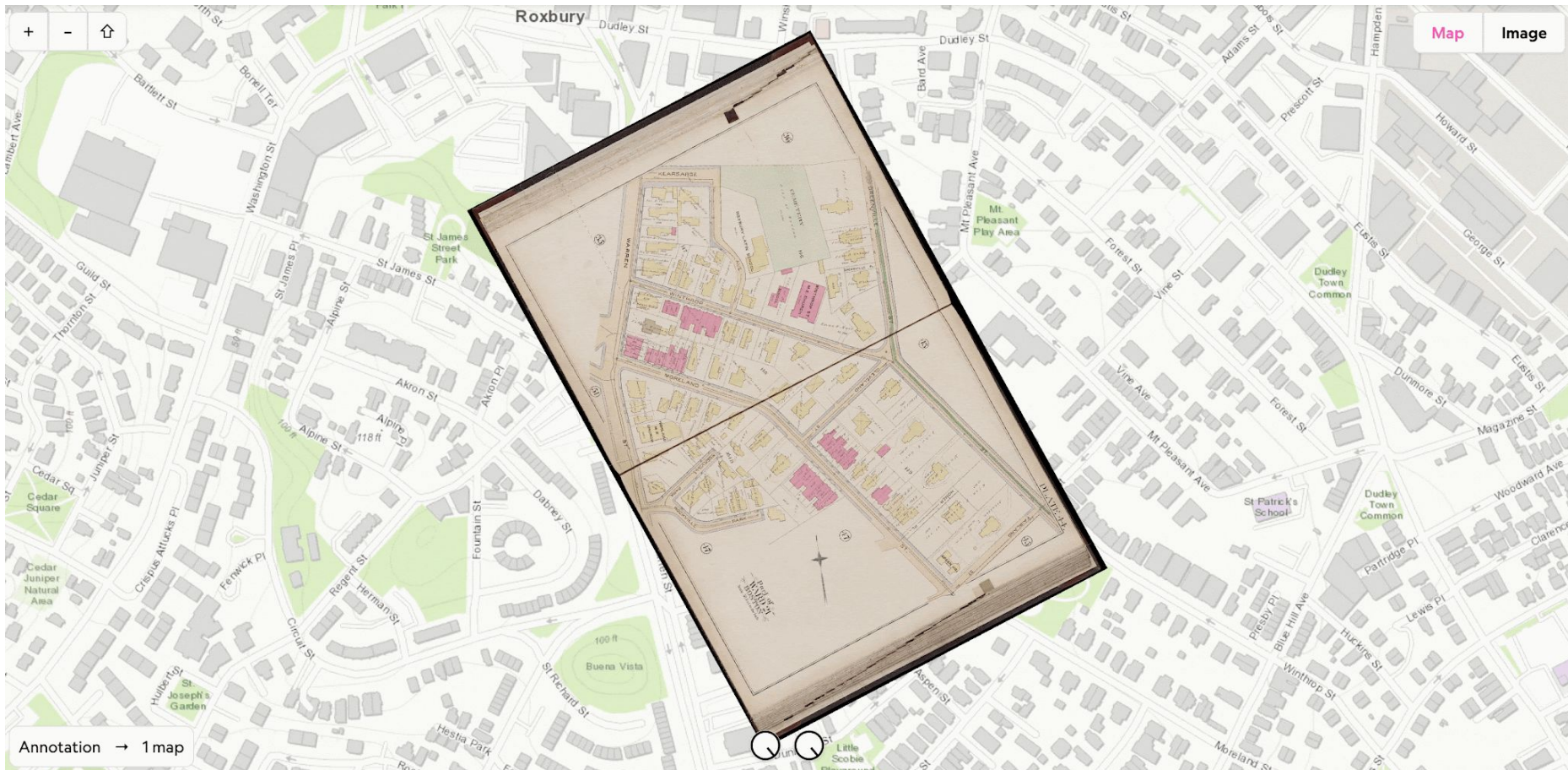
they can be produced in a couple
of different ways

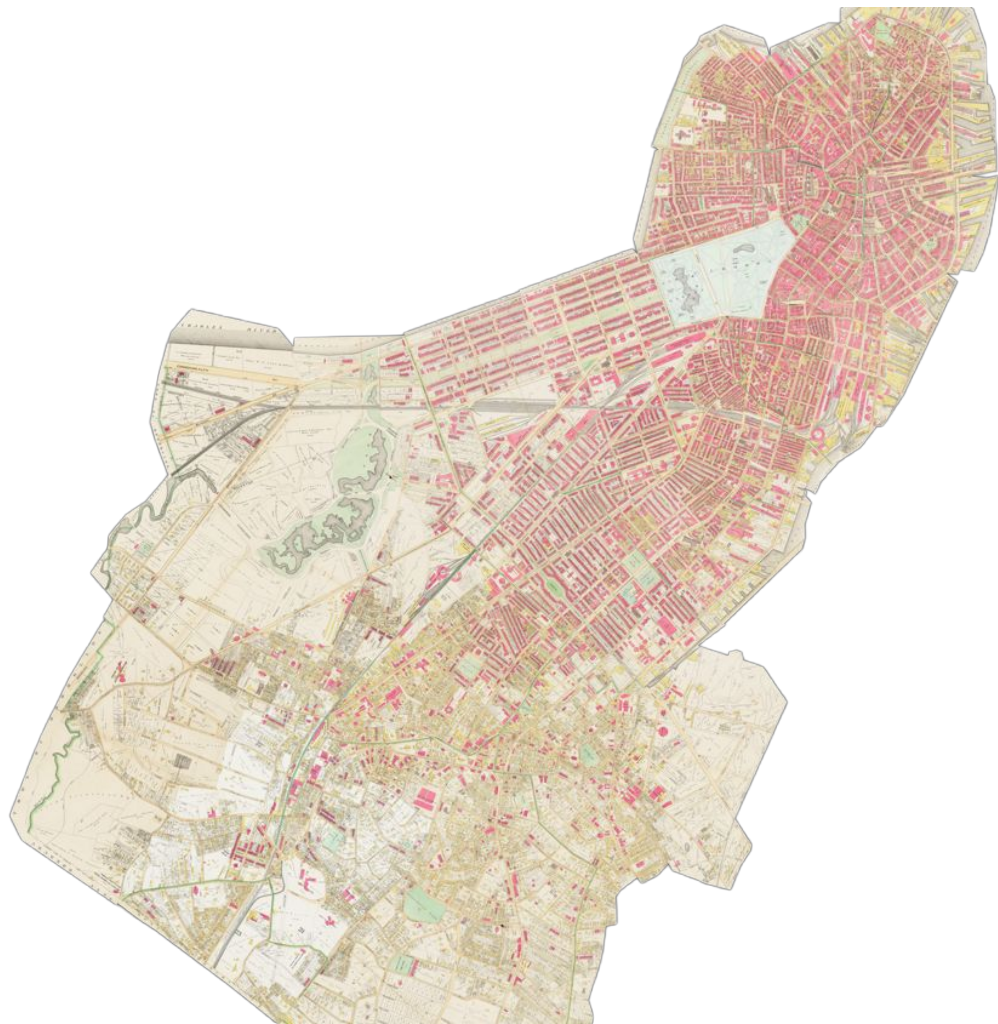
← this is purple but usually DEMs
are displayed in grayscale or a
photorealistic color ramp

**another
important kind of
raster data:**
scanned maps









**how do we go from the one on the left
to the one on the right?**



georeferencing

the process of adding spatial data to
scanned maps so they can be overlaid on
real-world geographies

step 1: *download raster layer*

step 2: *add raster layer*

step 3: *create control points*

step 4: *check for errors*

step 5: *save result*

**control points are
key**

good control points:

- street corners
- political boundaries
- old buildings (still here)
- well distributed

bad control points:

- water bodies
- non-intersections
- clustered in one place

transformation types

Zero-order polynomial	Minimum of one control point required
First-order polynomial	Minimum of three control points required
Adjust	Minimum of three control points required
Projective transformation	Minimum of four control points required
Second-order polynomial	Minimum of six control points required
Third-order polynomial	Minimum of ten control points required
Spline transformation	Minimum of ten control points required

transformation types

Zero-order polynomial	Minimum of one control point required
First-order polynomial	Minimum of three control points required
Adjust	Minimum of three control points required
Projective transformation	Minimum of four control points required
Second-order polynomial	Minimum of six control points required
Third-order polynomial	Minimum of ten control points required
Spline transformation	Minimum of ten control points required

**let's do some georeferencing
in sketch 02**