Application of GRASS GIS for the analysis of land cover in lake watersheds of Lithuania

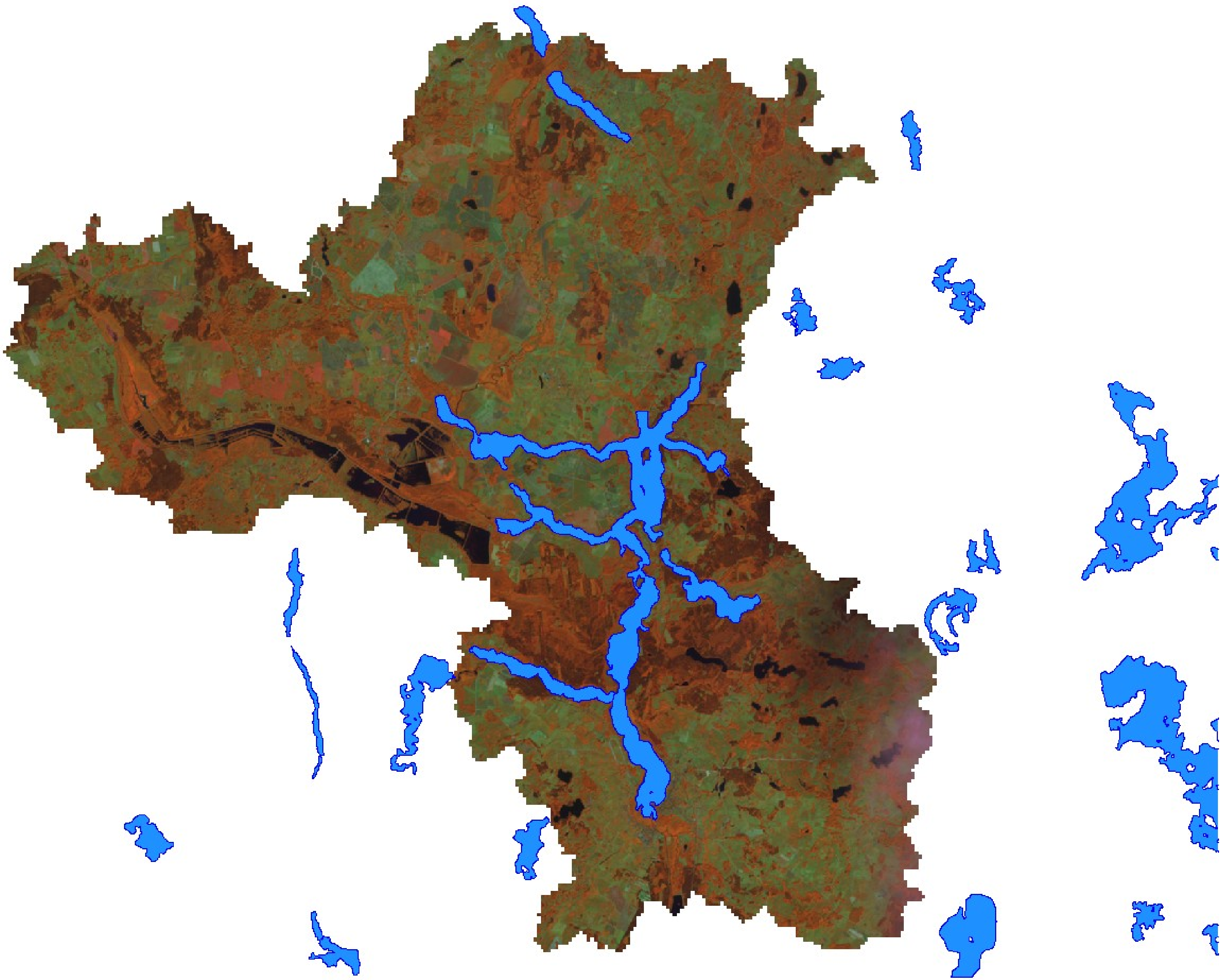
Dr. Gediminas Vaitkus

Applied Research Center
Institute of Aerial Geodesy
Kaunas, Lithuania
gedas.vaitkus@gmail.com

Background

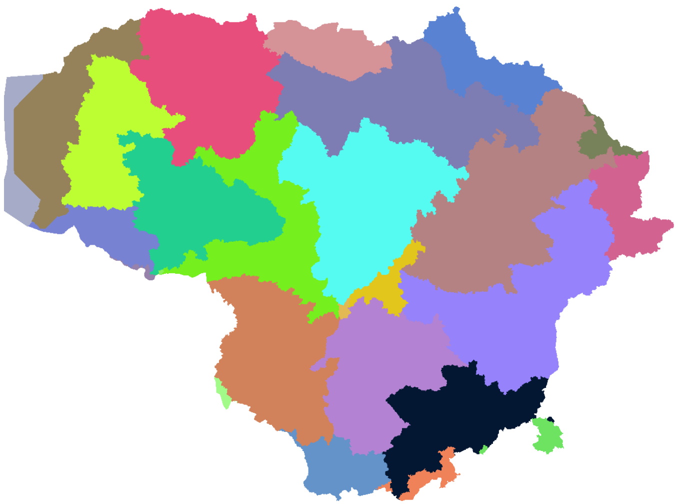
- Intensive agricultural practice, melioration and urban development after World War 2 deteriorated the environmental quality of many natural water bodies.
- Lithuanian EPA initiated a project on assessment of environmental conditions in all lakes and identification of the most polluted ones for further reclamation.
- Analysis of land cover structure in watersheds of ~350 lakes (>45 ha) was carried out as the first step in assessment of baseline environmental conditions in order to identify the most vulnerable ones for further *in situ* analysis and planning of recovery measures.
- “Traditional” concept of EU WFD could not be applied, as it deals with river basins and sub-basins, without taking lake basins into account. Dataset of lske watersheds was created with GRASS GIS software directly from SRTM3 DEM.
- “Traditional” GIS analysis methods could not be applied because of overlapping lake watersheds, therefore the entire GIS analysis process had to be designed and implemented on individual “lake-to-lake” basis.
- Technological solution to the problem was found in powerful scripting capabilities and advanced raster analysis functions of GRASS GIS software.
- Analysis of first results revealed that in most cases the generic analysis of land cover structure in lake watersheds is not sufficient, therefore in-depth land cover structure analysis in various ranges of lake surroundings, and even upstream rivers is necessary, making the GIS analysis process even more complicated, but still possible to implement in GRASS GIS.

Land cover analysis in lake watersheds

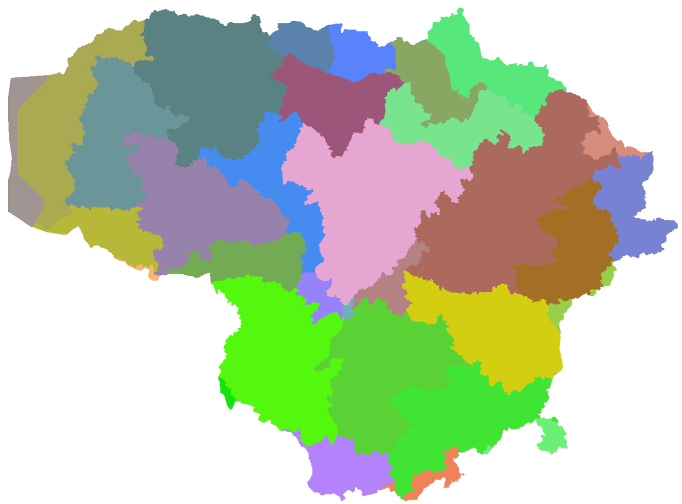


Watersheds (Lithuania)

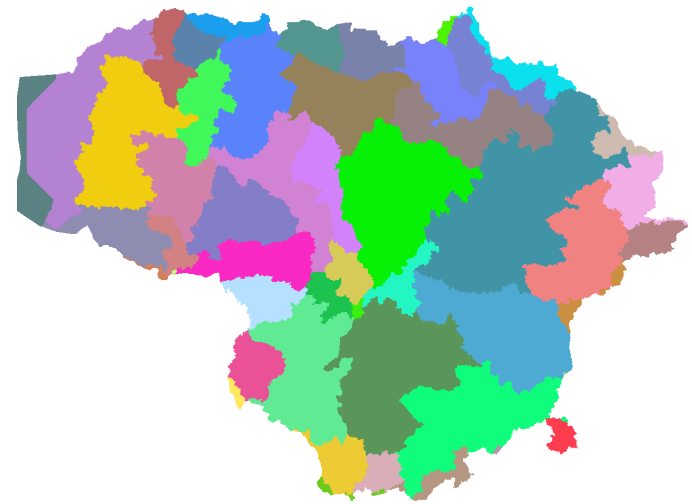
Watersheds were computed from SRTM3 CGIAR(4) DEM using GRASS *r.watershed* function
with different threshold values:



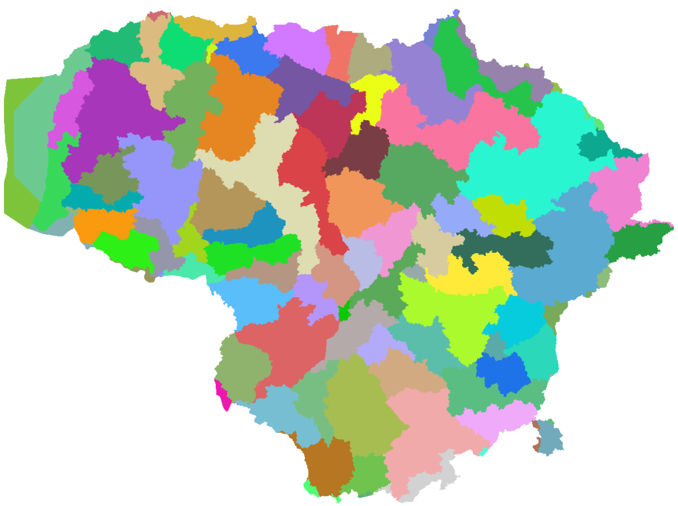
threshold = 300,000



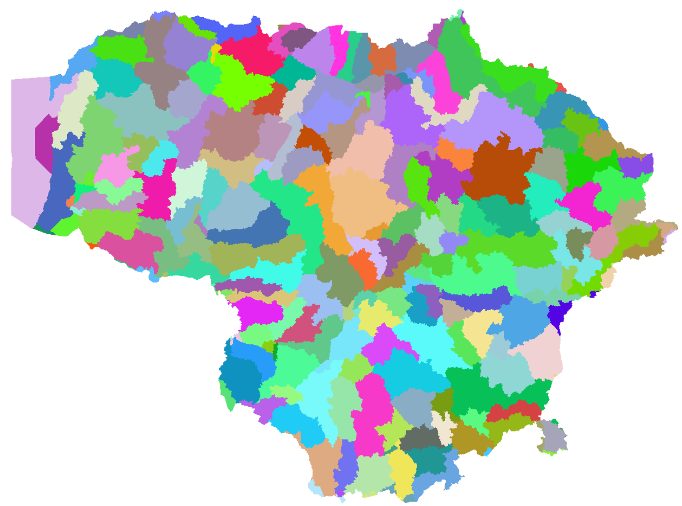
threshold = 200,000



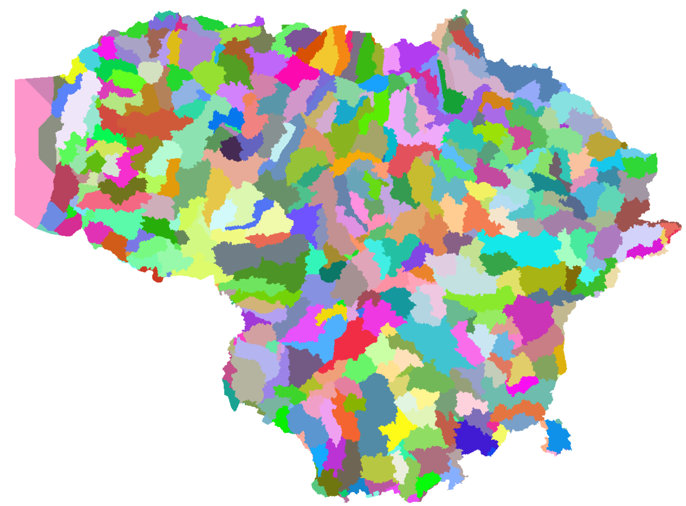
threshold = 100,000



threshold = 50,000

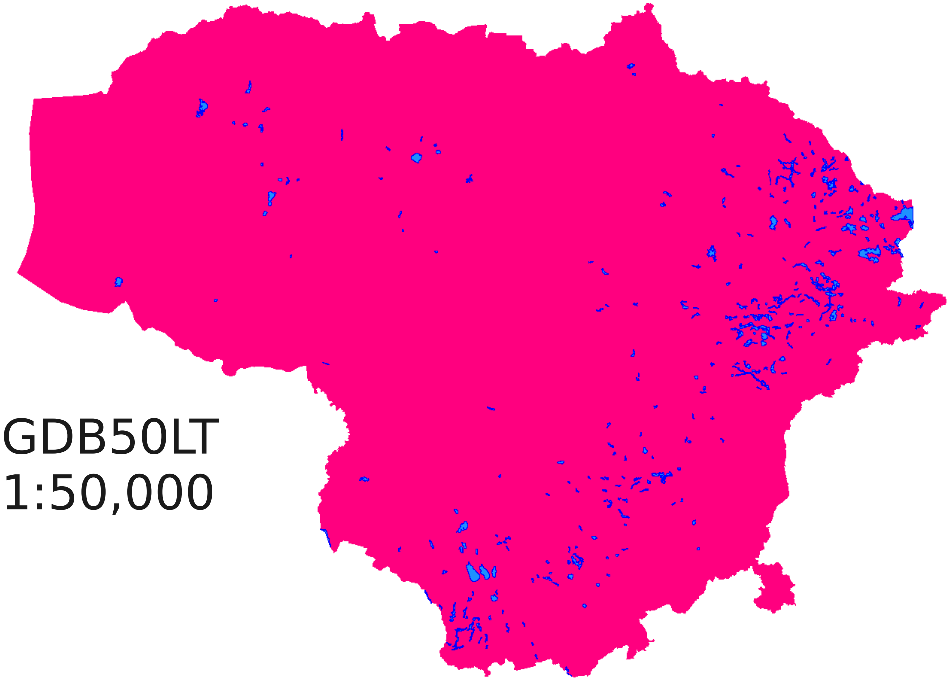


threshold = 20,000

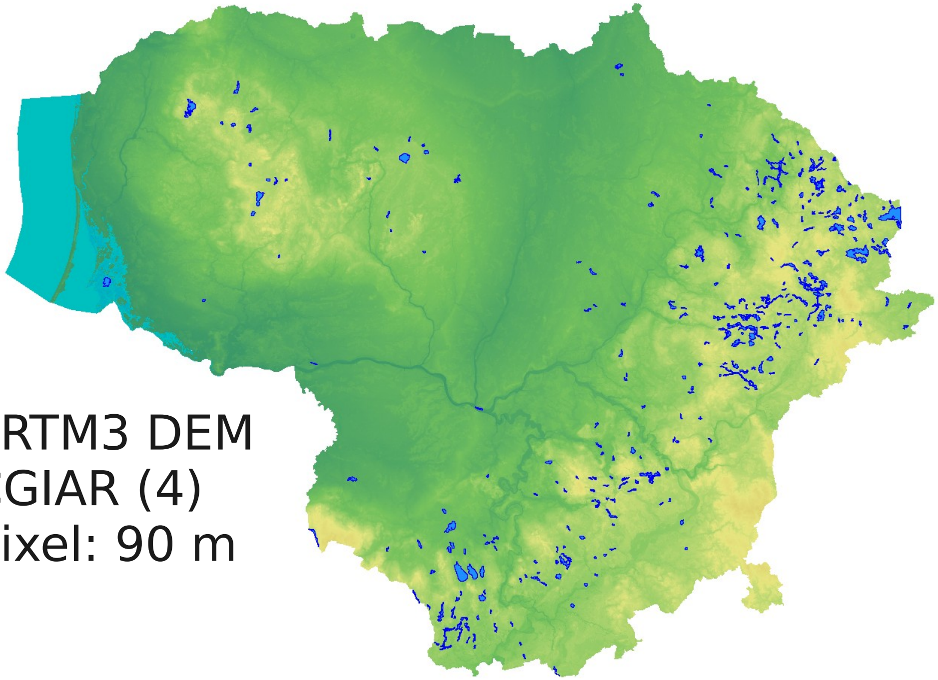


threshold = 10,000

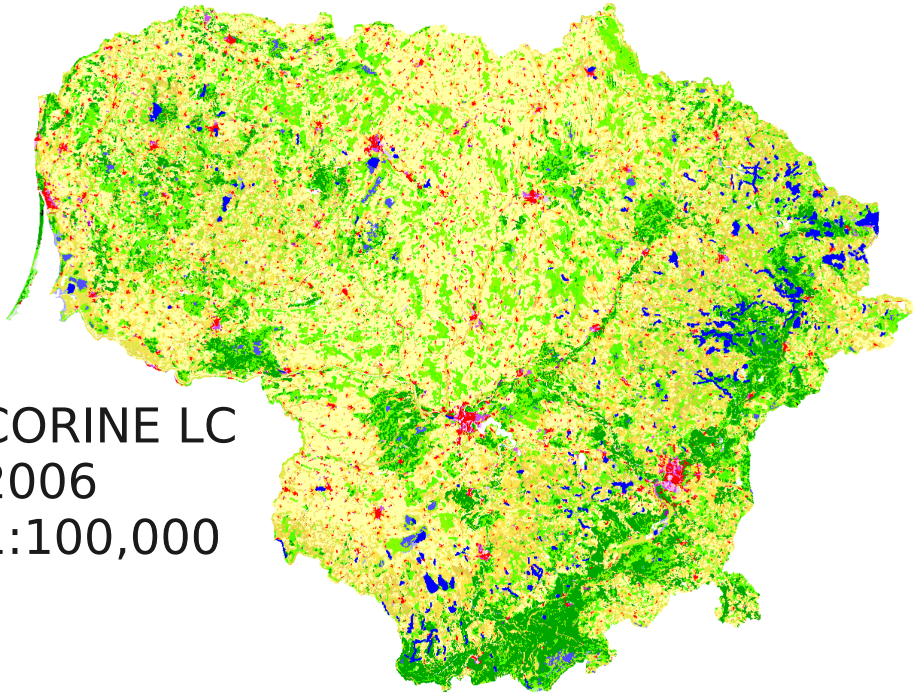
Datasets used for GIS analysis



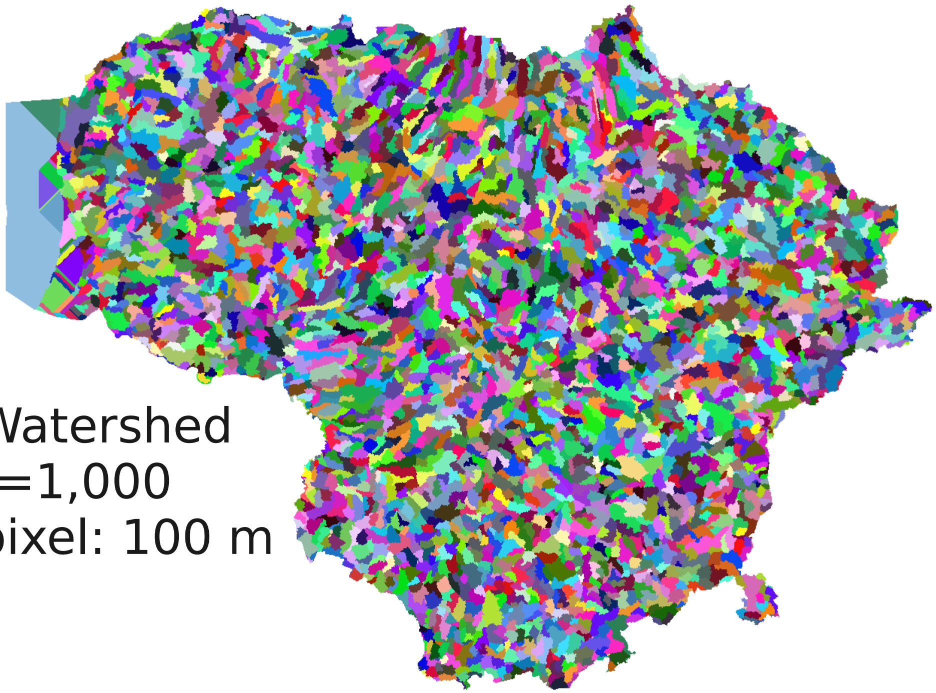
GDB50LT
1:50,000



SRTM3 DEM
CGIAR (4)
pixel: 90 m

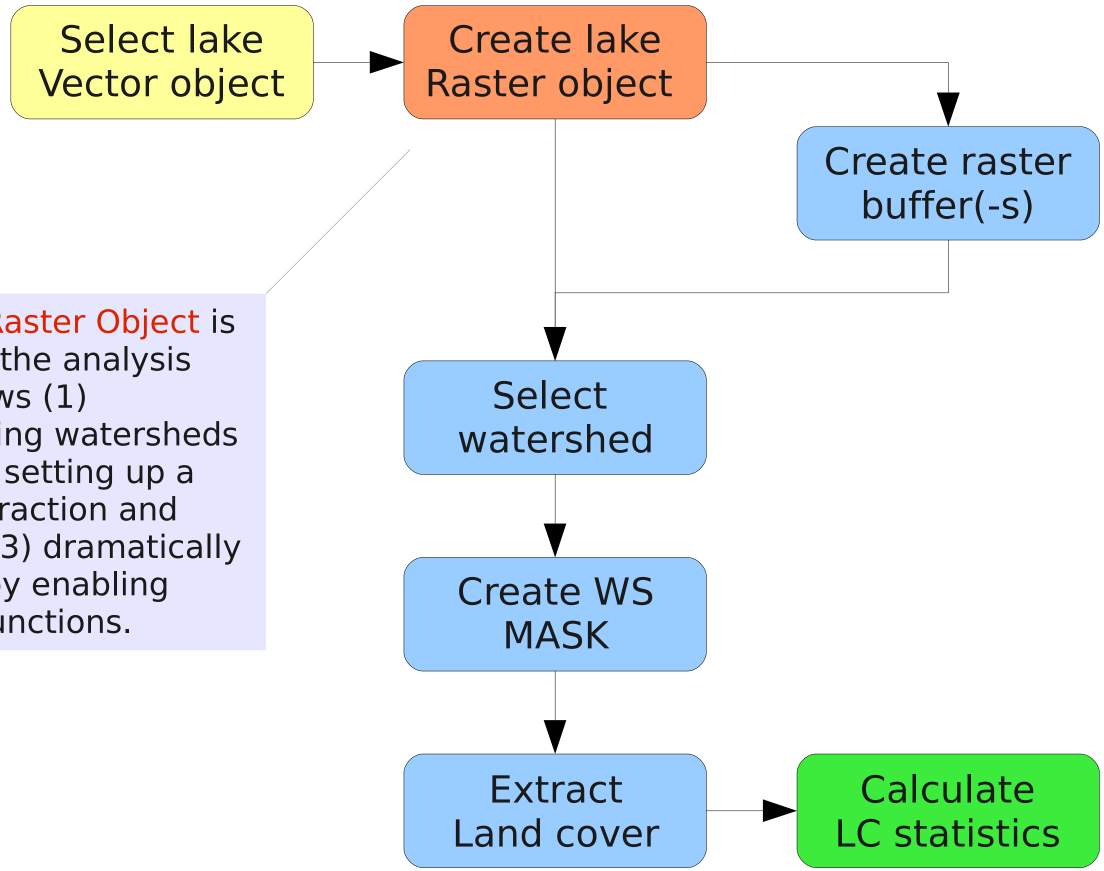


CORINE LC
2006
1:100,000



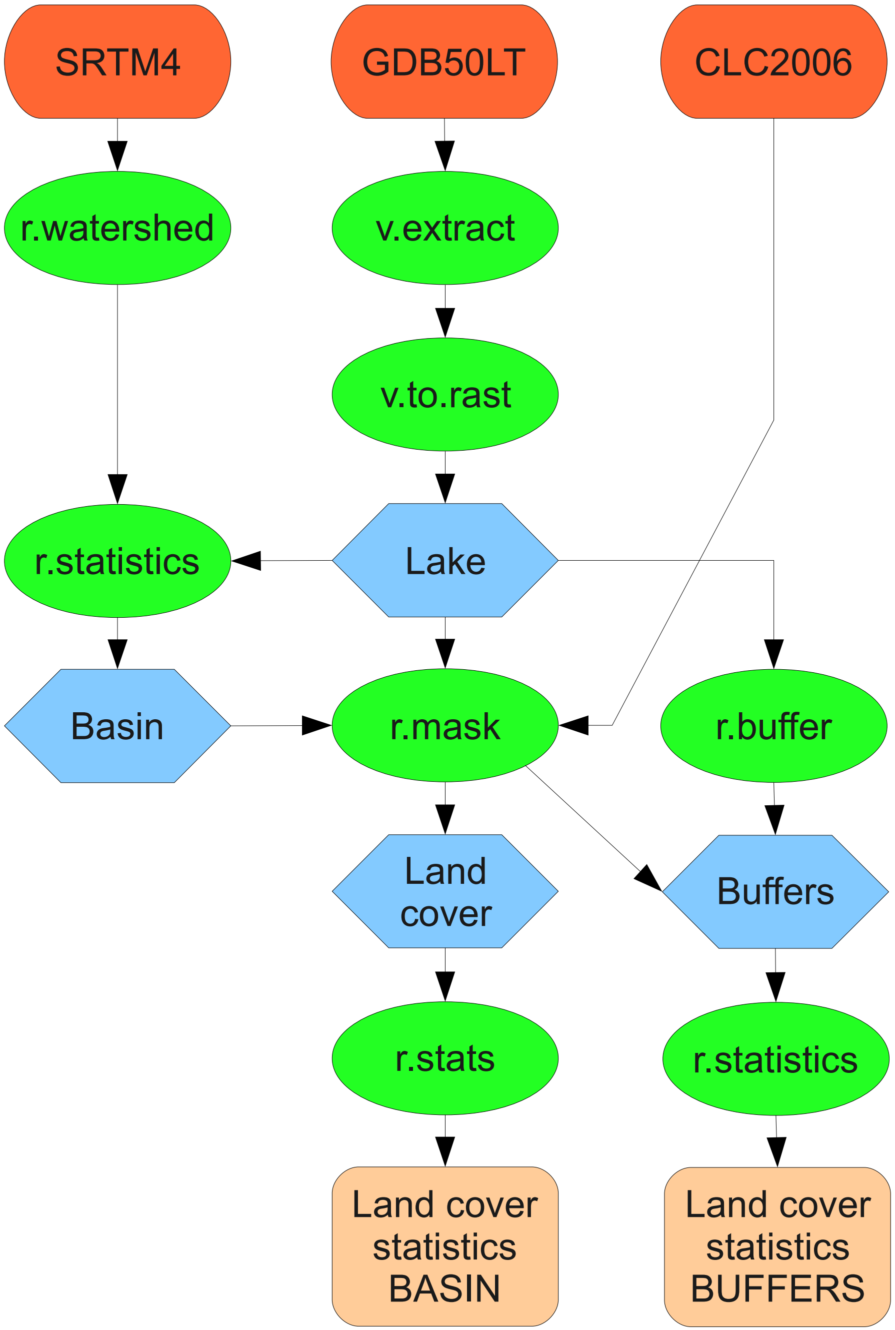
Watershed
t=1,000
pixel: 100 m

Land cover analysis schema



Creating a Single Lake Raster Object is an essential element of the analysis process, because it allows (1) identification of underlying watersheds of the selected lake, (2) setting up a MASK for land cover extraction and statistical analysis and (3) dramatically improver performance by enabling GRASS raster analysis functions.

Land cover analysis process



GIS analysis for each lake was performed by a **GRASS script**, with the following steps:

1. Selection of a certain lake from vector database and transforming vector feature into raster

    v.extract; v.to.rast

2. Identification of the drainage area (selection of the nearest watersheds) and setting the MASK parameter for further processing

    r.mask {...} *maskcats*="..."

3. Creation of raster buffer zones around the lake (within masked area) for further analysis

    r.buffer {...} *distances*={...}

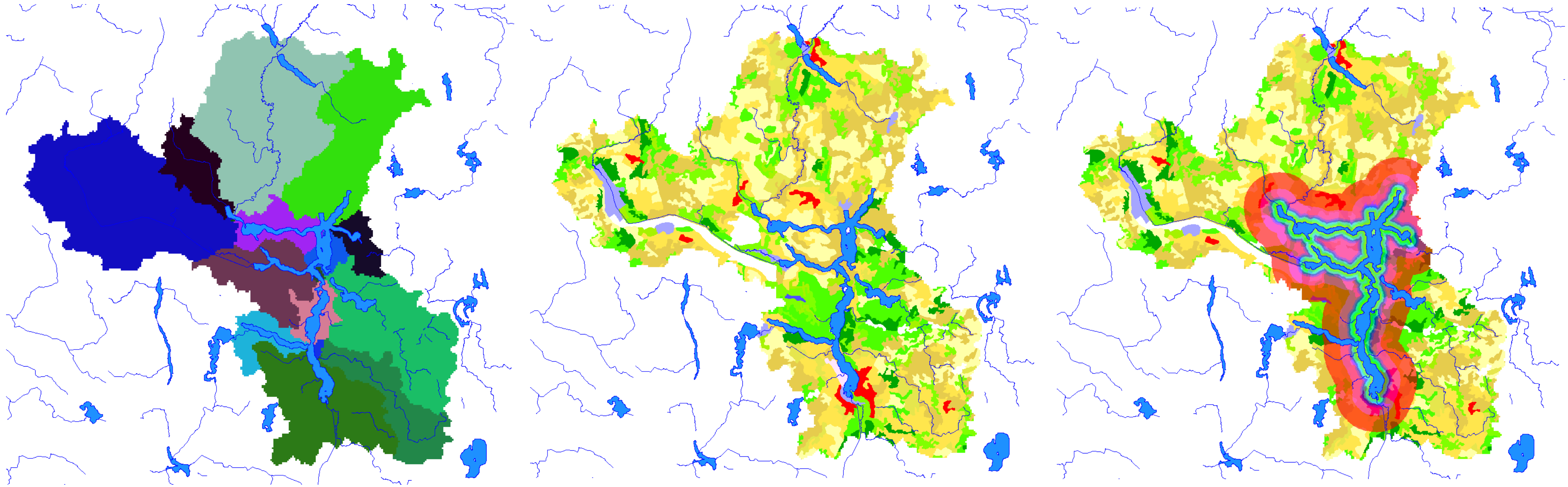
4. Statistical summary of CORINE LC classes (areas, %) in the masked area of the lake watershed

    r.stats {...} > *result.txt*

5. Statistical summary of CORINE LC classes (areas, %) in the buffer zones of the lake watershed

    (*r.statistics* {...} *method=distribution* > result.txt

Land cover analysis process



1. Identification of the drainage area (selection of the nearest watersheds);

2. Setting up the MASK for further processing;

3. Subset of the CORINE LC dataset, elimination of “water” CLC classes;

4. Statistical summary of CLC classes (areas, %) in the masked area of the lake watershed;

5. Creation of raster buffer zones around the lake (within masked area);

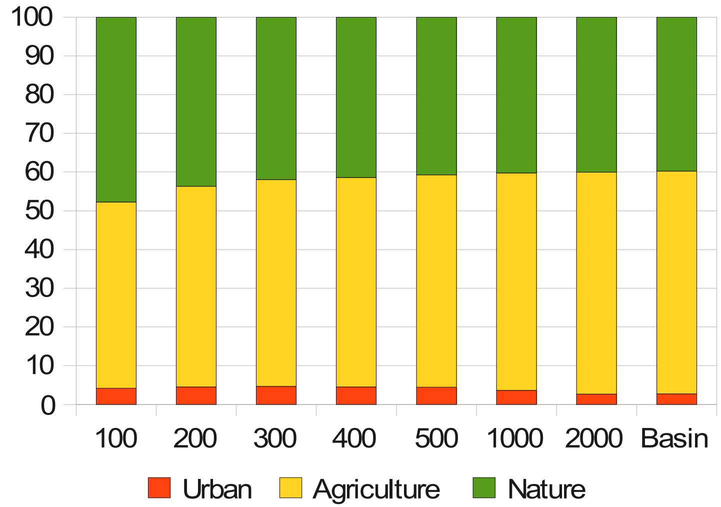
6. Statistical summary of CLC classes (areas, %) in the buffer zones of the lake watershed.

GRASS GIS script

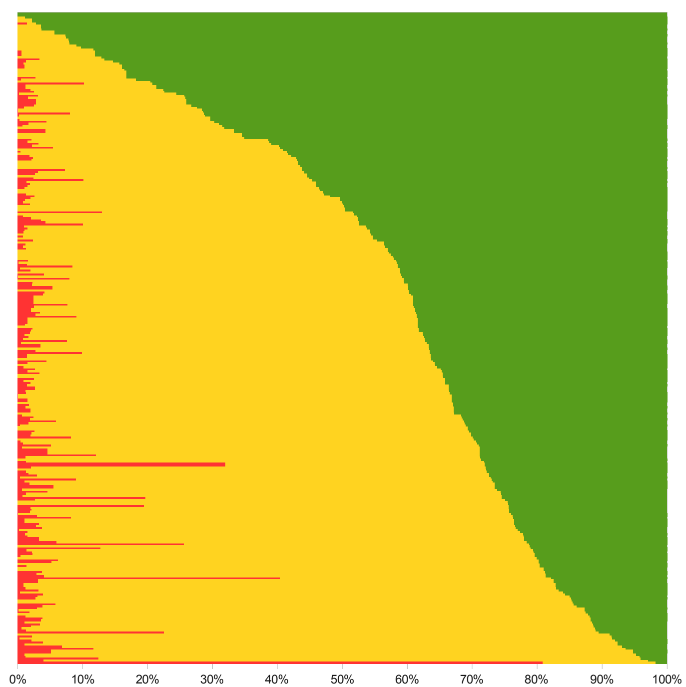
```
#!/bin/sh
if test "$GISBASE" = ""; then
   echo "You must be in GRASS to run this program."; exit
fi
# set up the obligatory command-line parameters for the shell script:
# (1) lakes vector dataset, (2) watersheds dataset, (3) land cover dataset,
# (4) output (text) file name
LAKES=$1
WATERSHEDS=$2
LANDCOVER=$3
OUTPUT=$4

# you can change mapset resolution (res= parameter) in the next line:
g.region -d -p --overwrite save=mapset.region res=25
v.db.select -c $LAKES column=cat > lakes_cat.txt
max=`wc -l lakes_cat.txt | cut -d" " -f1`
for i in `seq 1 $max` ; do
   g.remove --quiet -f rast=lake,buffer,extract_bas,extract_buf vect=lake
   r.mask --quiet -r input=MASK
   clear
   echo "Total N of objects   = $max"
   echo "Processing object No = $i"
   polygon=`sed -n '1,1p' lakes_cat.txt`
   sed '1,1d' lakes_cat.txt > lakes_cat_1.txt
   cp -f lakes_cat_1.txt lakes_cat.txt
   echo "Processing object Id = $polygon"
   v.extract $LAKES output=lake type=area list=$polygon
   v.to.rast input=lake output=lake type=area column=cat
   r.mapcalc "extract_bas = if(lake,$WATERSHEDS)"
   basin=`r.stats -n input=extract_bas fs=tab
     | sed -e :a -e N -e 's/\n/ /' -e ta`
   echo "Codes of lake basins = $basin"
   r.mask --quiet -o input=$WATERSHEDS maskcats="$basin"
   g.region rast=MASK res=25
   r.stats -a -p -n input=$LANDCOVER fs=tab \
        | awk '{ print '$polygon', "0", $1, $2, $3 }' >> $OUTPUT
   # compute LC stats in buffers: 250 500 1000 2000 m
   # you can change buffer distance values in the following line:
   for buffer in 250 500 1000 2000 ; do
      echo "Processing buffer No = $buffer"
      r.buffer input=lake output=buffer distances=$buffer
      r.mapcalc "extract_buf = if(buffer,$LANDCOVER)"
      r.stats -a -p -n input=extract_buf fs=tab \
        | awk '{ print '$polygon', '$buffer', $1, $2, $3 }' >> $OUTPUT
      g.remove --quiet -f rast=buffer,extract_buf
   done
done
g.region --overwrite region=mapset.region res=25
g.remove --quiet -f rast=lake,buffer,extract_bas,extract_buf vect=lake
r.mask --quiet -r input=MASK
rm -f lakes_cat*
```

1. Set up input layers for processing
2. Identify objects for processing
3. Analyze LC stats in the lake watershed
4. Analyze LC stats in the selected Buffers within lake watershed
5. Clean-up of the system

Results of GIS analysis: Generic land cover structure



Buffer	Urban	Agriculture	Nature
100	4.2	48.1	47.7
200	4.5	51.8	43.7
300	4.6	53.4	42.0
400	4.5	54.1	41.4
500	4.5	54.8	40.7
1000	3.6	56.1	40.2
2000	2.7	57.3	40.0
Basin	2.7	57.5	39.8



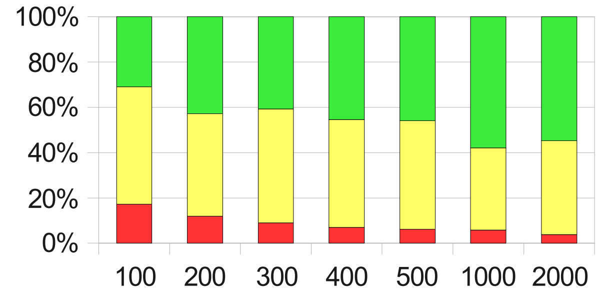
Analysis of land cover statistics sample of ALL lake watersheds indicated, that proportion of natural and urban elements tends to decrease, while agricultural elements – increase within increasing distance from the lake.

It became evident, that on the general basis land cover proportions stabilize within the distance of 1 km from the lake, remaining the same as those of the entire lake watershed.

However, land cover structure variations within various distances of certain lakes often are very significant and totally different from the generic proportions, therefore individual analysis must be applied to each lake.

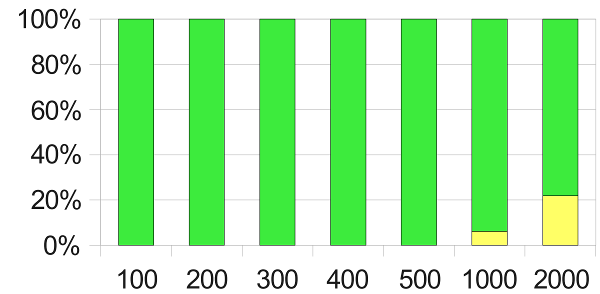
Results of GIS analysis: Land cover patterns in different lakes

Lake	Buffer	Urban	Agriculture	Nature
34312	100	17.22	51.88	30.91
Beržoras	200	11.96	45.18	42.86
Plungės	300	8.99	50.25	40.77
50.6	400	7.03	47.55	45.41
	500	6.15	47.97	45.87
	1000	5.79	36.32	57.89
	2000	3.86	41.47	54.67



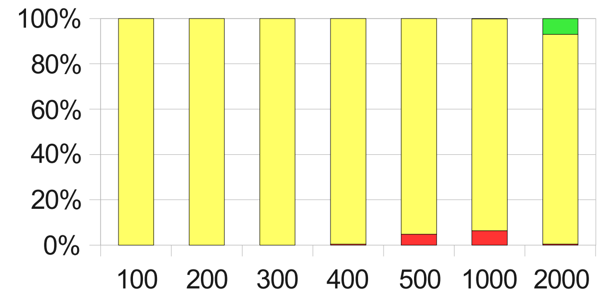
1. Mixed LC:
Urban, Agricultural and Natural landscape elements are present at various proportions

Lake	Buffer	Urban	Agriculture	Nature
42110	100	0	0	100
Alnis	200	0	0	100
Molėtų	300	0	0	100
102.6	400	0	0	100
	500	0	0	100
	1000	0	6.12	93.88
	2000	0	21.94	78.06



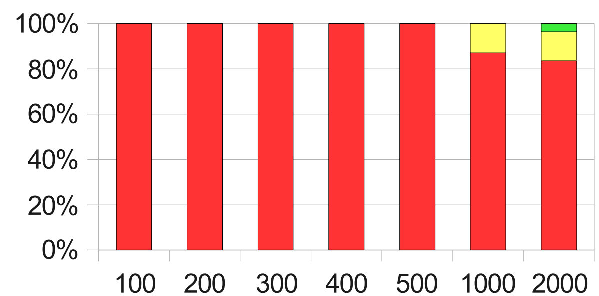
2. Natural LC:
Natural landscape elements dominate (>50%)

Lake	Buffer	Urban	Agriculture	Nature
41962	100	0	100	0
Ilgajis	200	0	100	0
Ukmergės	300	0	100	0
56.93	400	0.42	99.58	0
	500	4.8	95.2	0
	1000	6.32	93.56	0.12
	2000	0.38	92.69	6.93



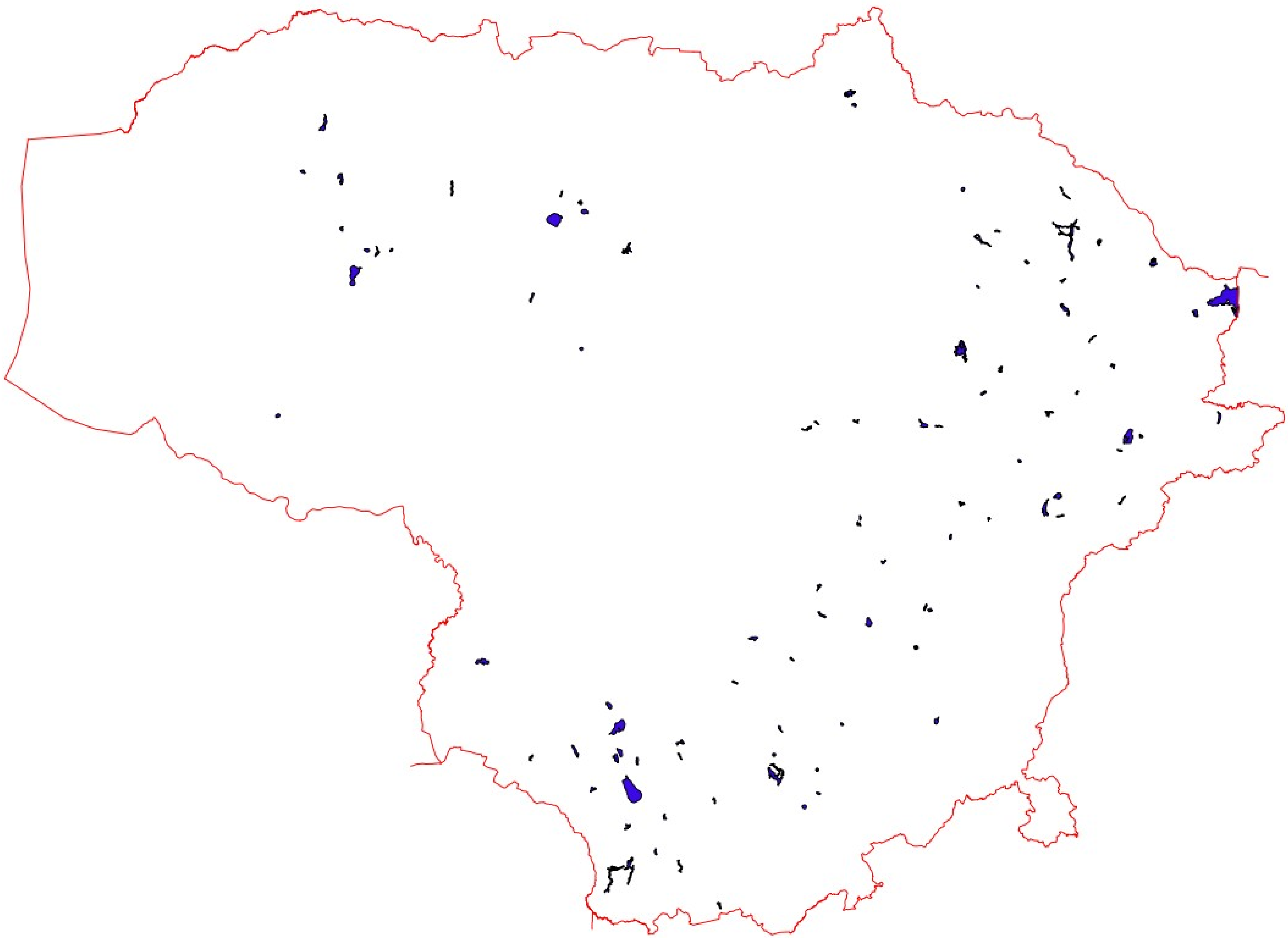
3. Agricultural LC:
Agricultural landscape elements dominate (>50%)

Lake	Buffer	Urban	Agriculture	Nature
34763	100	100	0	0
Talkša	200	100	0	0
Šiaulių	300	100	0	0
56.57	400	100	0	0
	500	100	0	0
	1000	87.07	12.93	0
	2000	83.74	12.67	3.59

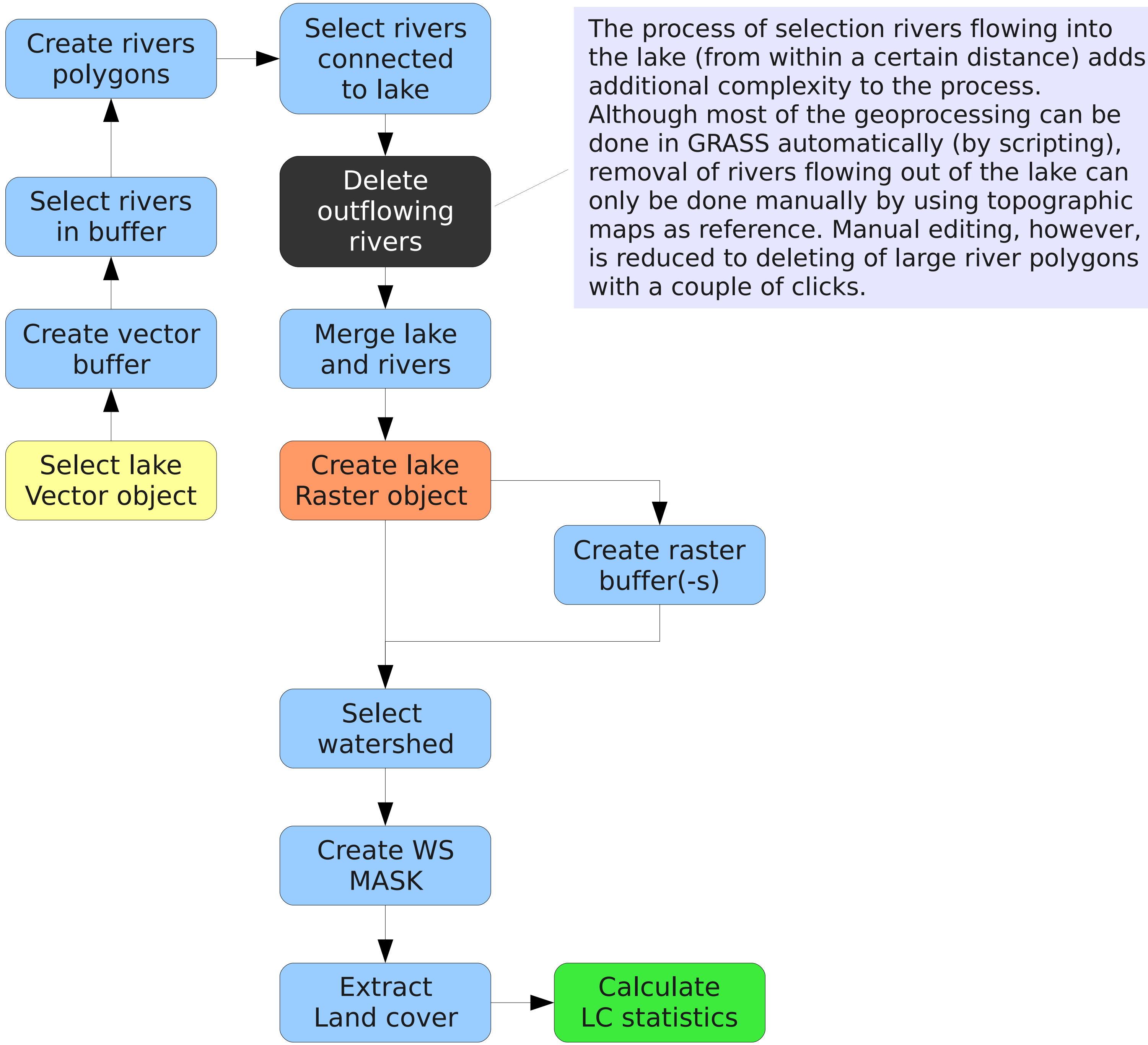


4. Urban LC:
Urban landscape elements dominate (>50%)

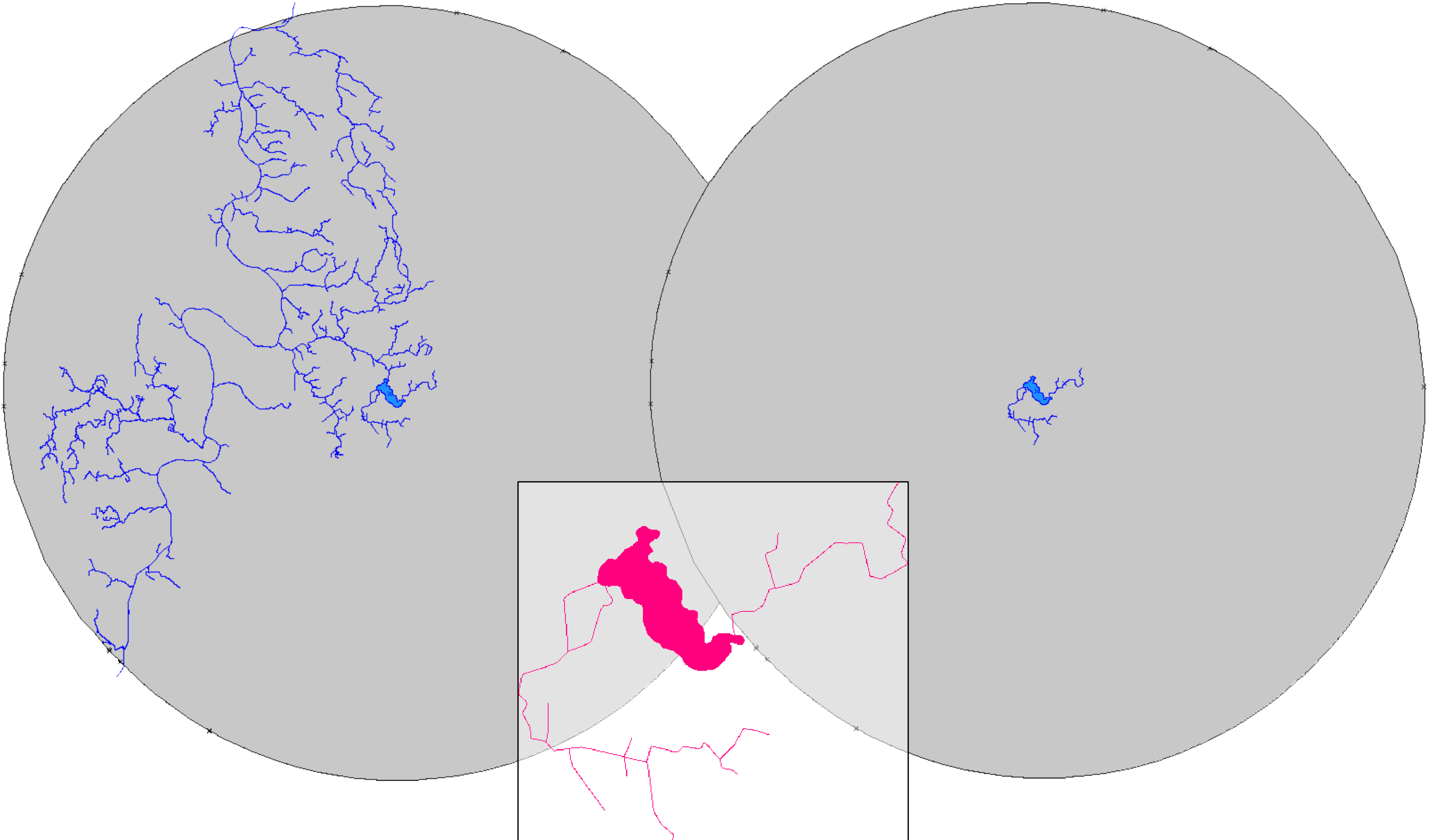
Identified “problematic” lakes



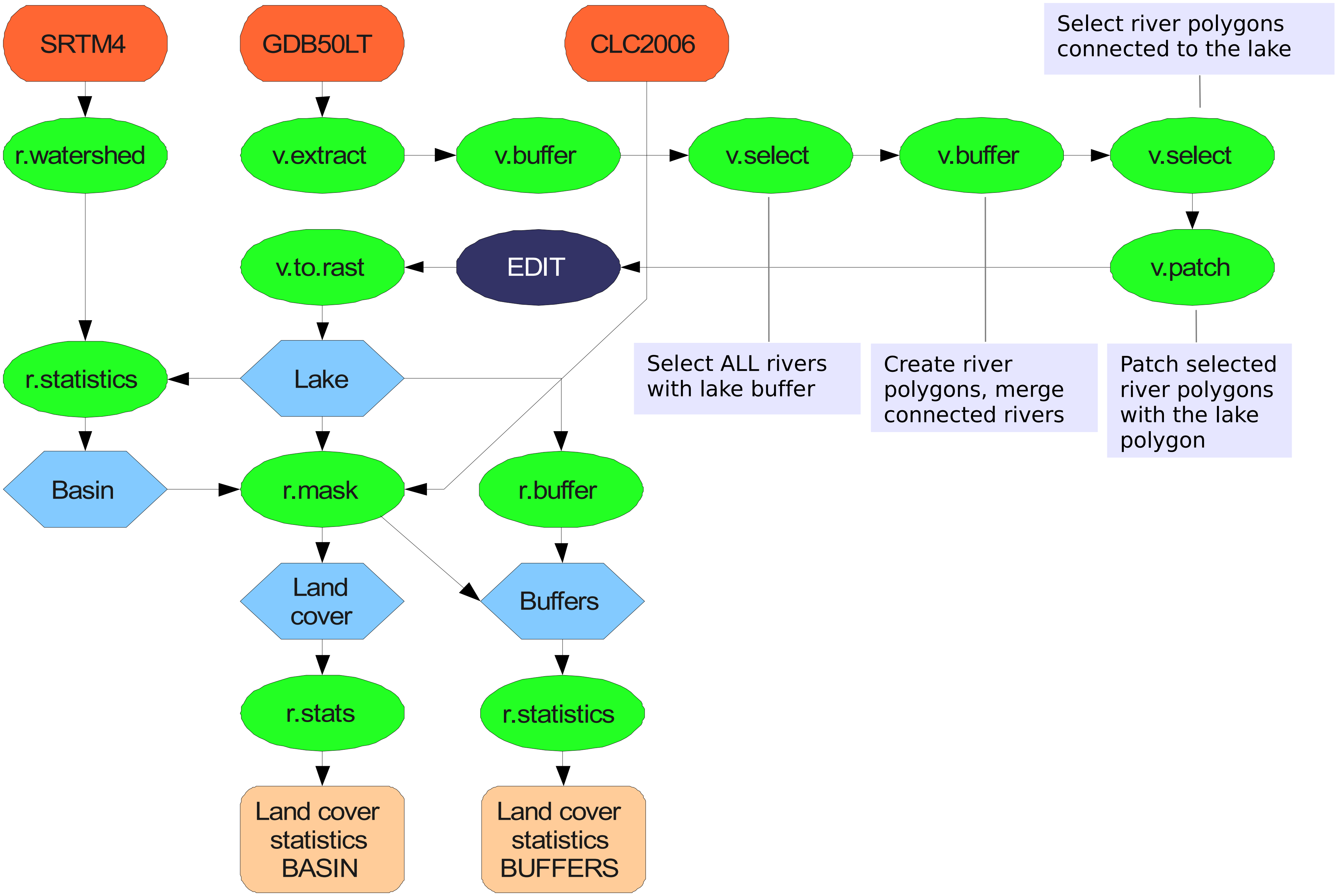
Further: lakes and river inflows



Extraction of river inflows



Processing chain under testing



The work continues

- Accumulative land cover statistics within different distances from lakes;
- Land cover statistical analysis over watersheds covering both lakes and inflowing rivers;
- Replacement of land cover codes with “environmental scoring values” and computing “land cover environmental indices” for each pixel, as well as total scores for lake buffers/watersheds;
- Introduction of additional elevation-related elements (like slope) into the model and compute environmental indice X slope interaction values for pixels and watersheds in order to identify “critical areas” of lake watersheds, which are most likely to cause agricultural and urban contamination of lakes;
- Run cluster analysis on land cover statistics and identify major “ecological types” of lakes, which may need different management approaches.

Thank you !

Dr. Gediminas Vaitkus

Institute of Aerial Geodesy
Applied Research Center
Pramones 13, 51327 Kaunas, Lithuania
TEL: +370 37 755226; GSM: +370 620 72870
FAX: +370 37 451497
gedas.vaitkus@gmail.com