

**Effects of Historic and Current Land Covers on
Water Budget and Water Quality in Agricultural
Regions of Michigan and Wisconsin:
SWAT Model Report 040500 (Grand Basin)**



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1.0 General Information

The Grand six digit HUC contains two major catchments: The Grand River and the Kalamazoo River. The basin lies on the southwest edge of Michigan's Lower Peninsula. The basin, as the rest of the Peninsula, has a mild topography. The minimum elevation is 176m and the maximum elevation reads 381m with a mean of 276m. The catchment has a total area of 2.16 million hectares (or 5.33 million acres). The relief map is shown in figure 1.

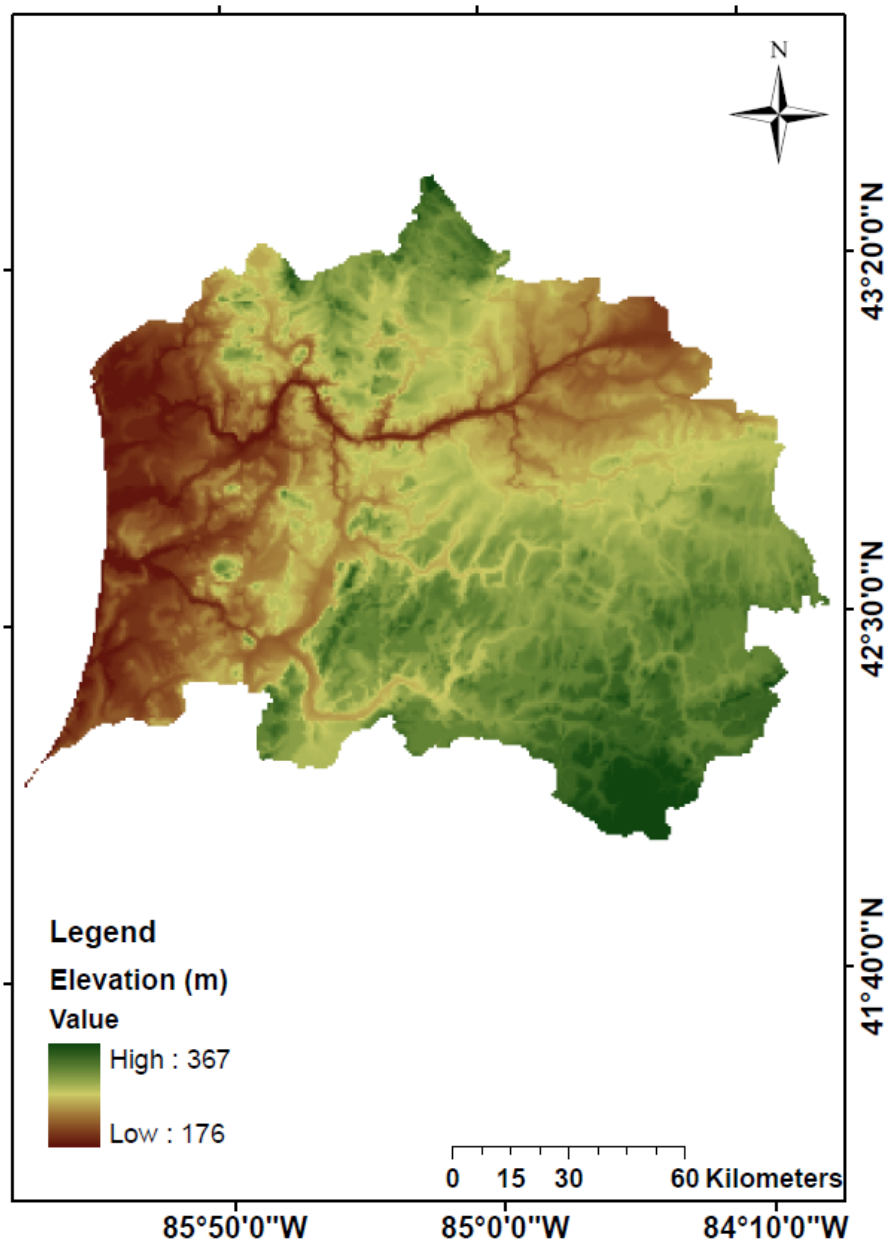


Figure 1. Relief map of the Grand Basin

2.0 River Network

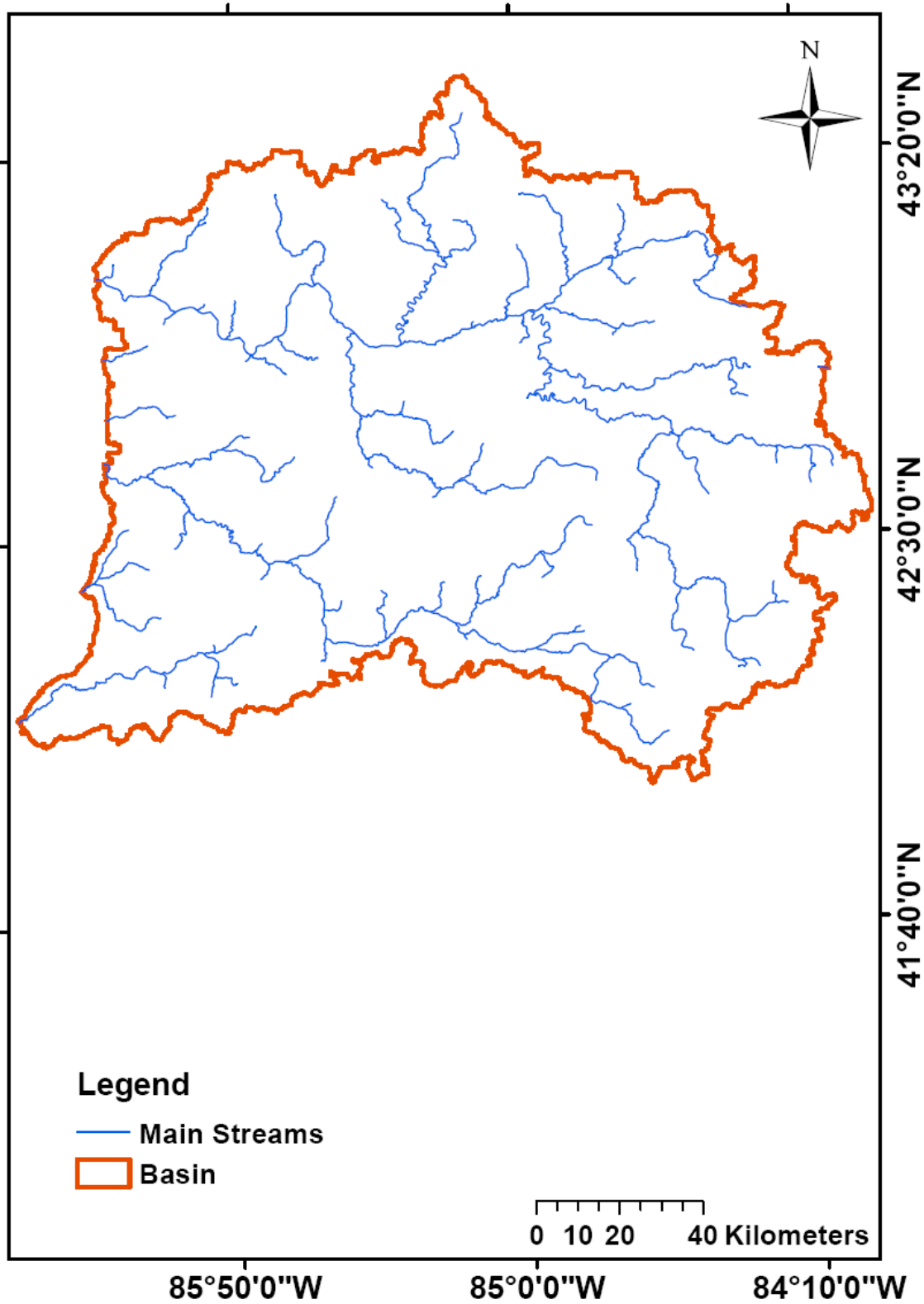


Figure 2. Major streams of the Grand Basin

3.0 Landuse/Land Cover map

Two set of maps were used in this study.

- 1) 2001 National Land Cover Dataset (NLCD 2001)
- 2) Landuse Circa 1800 County Base (LU1800) Edition: 1.

Based on the 2001 National Land Cover Dataset, cropland in the Grand Basin Watershed is the predominant land usage covering 51 percent of land area. Forest covers 17 percent of the land area. Urban areas, wetlands, rangelands, and water constitute the remaining 32 percent of land cover (Tables 1a and 1b). In the Grand Basin, forest and wetland dominates its northeast upland and agricultural land occupies a majority of the middle plane and the west (Figure 3). Rangeland and hay farming scatter through the middle and southern section; and two urban centers are found in the basin.

Table 1a. Landuse of the Grand Basin ranked by area (NLCD 2001)

LANDUSE:	AREA (ha)	Percentage
Agricultural Land-Row Crops	785061.4	36.4
Forest-Deciduous	330217.2	15.3
Hay	321659.6	14.9
Wetlands-Forested	260099.9	12.1
Residential-Low Density	158950.6	7.4
Residential-Medium Density	115112.4	5.3
Range-Grasses	43934.7	2.0
Water	35460.4	1.6
Residential-High Density	33622.9	1.6
Forest-Evergreen	19663.9	0.9
Forest-Mixed	17193.0	0.8
Industrial	14759.0	0.7
Range-Other	8475.0	0.4
Wetlands-Non-Forested	7056.2	0.3
Range-Brush	6318.7	0.3

Table 1b. Landuse of the Grand Basin given by coarse classification (NLCD 2001)

Agriculture	51.3%
Forest	17.0%
Urban	15.0%
Wetland	12.4%
Range	2.7%
Water	1.6%

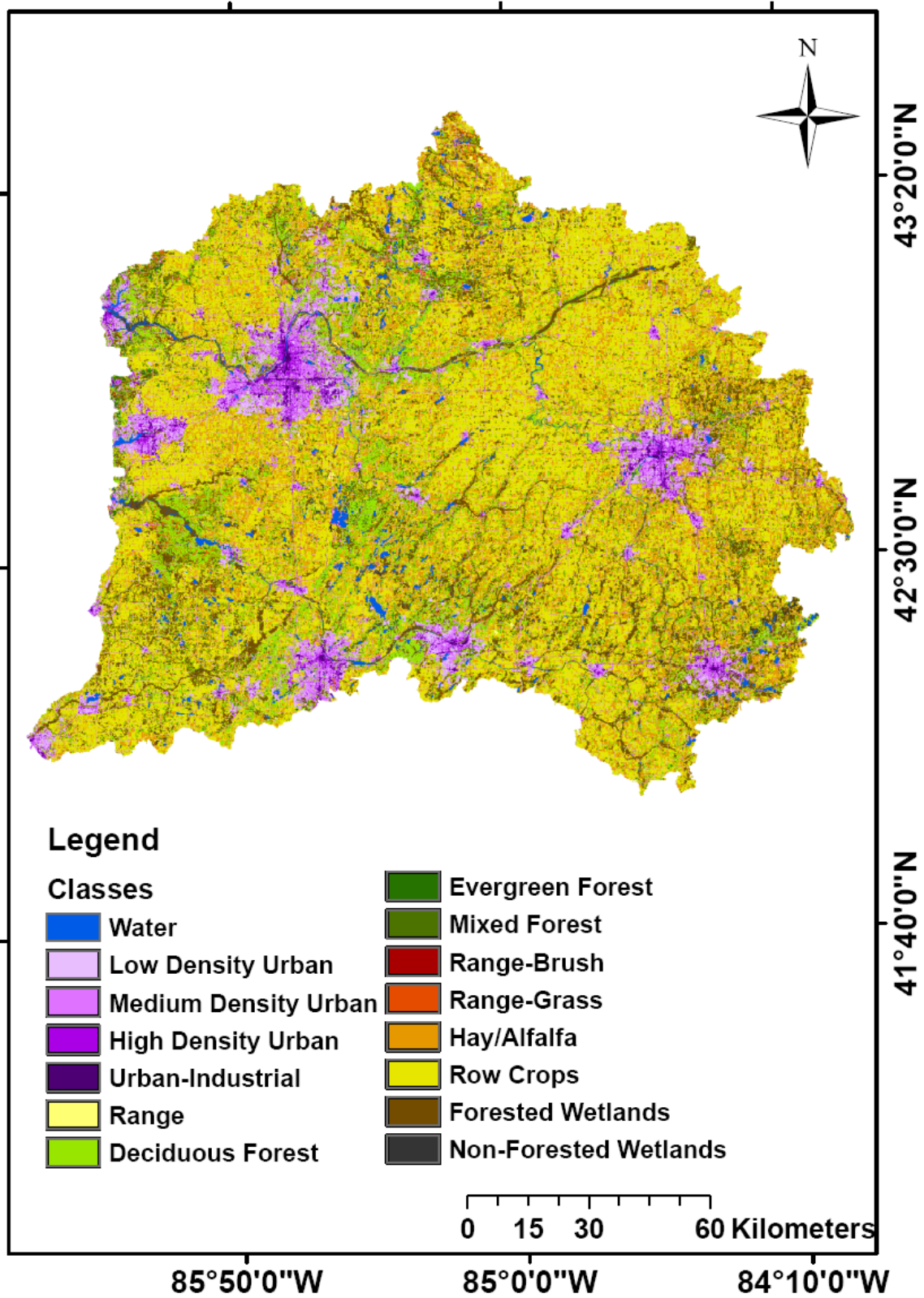


Figure 3. Current landuse map of the Grand Basin

Based on the Landuse circa 1800 county base (LU1800), forest is the predominant land usage in the Grand Basin covering 72percent of land area. Wetlands cover 16 percent of the land area. Rangeland and water constitute the remaining 12 percent of land cover (Tables 2a and 2b). In the Grand Basin, mixed forest dominates its northern area and rangeland and deciduous forest area found throughout the southern area (Figure 4). Wetlands are scattered throughout the basin.

Table 2a. Landuse of the Grand Basin ranked by area (LU1800)

LANDUSE:	AREA (ha)	PERCENTAGE
Forest-Mixed	1023862.0	47.5
Forest-Deciduous	486121.3	22.5
Wetlands-Forested	251936.0	11.7
Range-Brush	217934.6	10.1
Wetlands-Non-Forested	87511.8	4.1
Forest-Evergreen	51602.1	2.4
Water	34423.6	1.6
Range-Grasses	3395.1	0.2
Rye	677.8	0.0
Range-Other	76.4	0.0

Table 2b. Landuse of the Grand Basin given by coarse classification (LU1800)

Forest	72.4%
Wetland	15.7%
Rangeland	10.3%
Water	1.6%
Urban	0.0%
Agriculture	0.0%

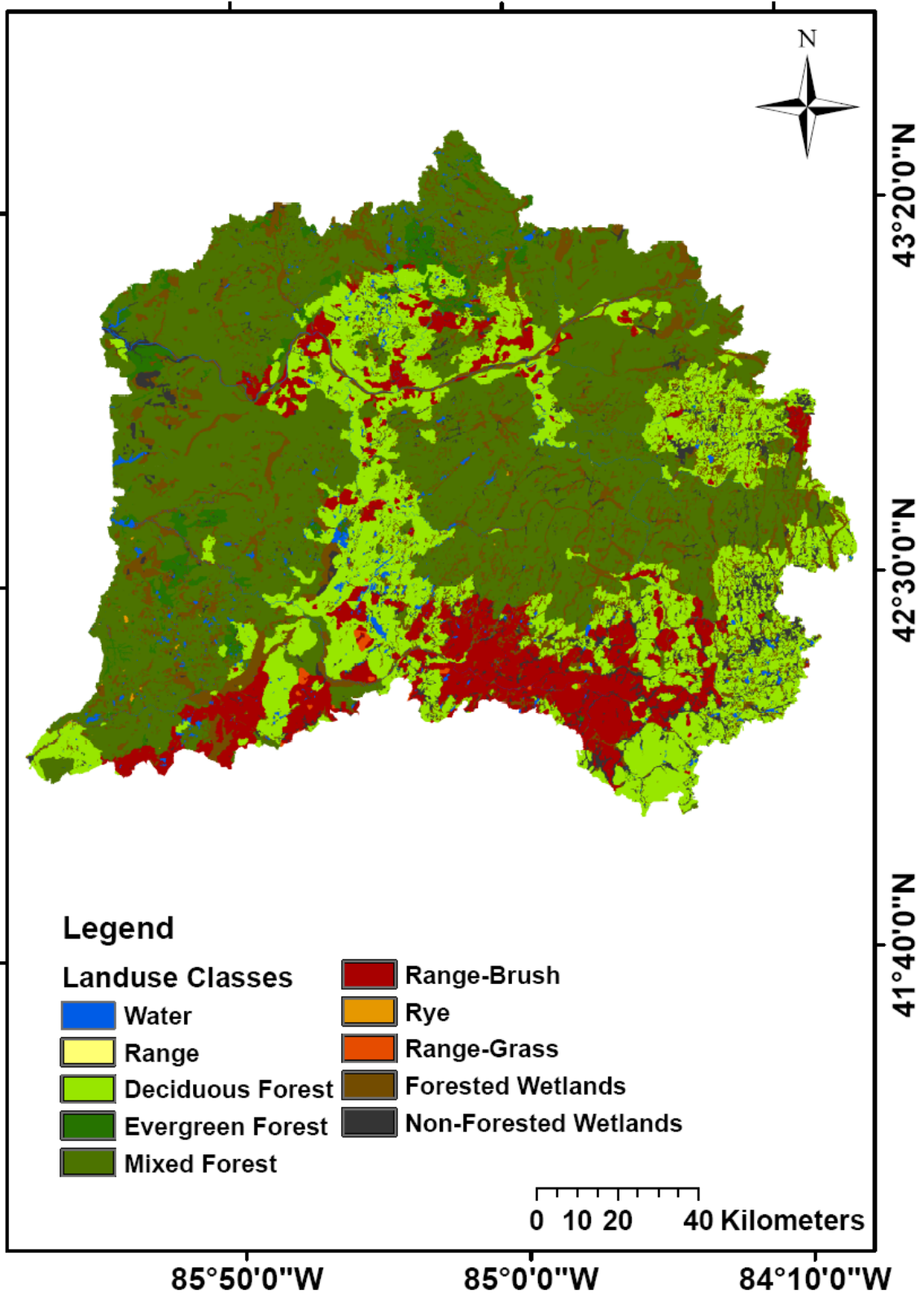


Figure 4. Pre-Settlement landuse map of the Grand Basin

4.0 Hydrologic Soil Groups

The Natural Resources Conservation Service (NRCS) - National Cartography and Geospatial Center (NCGC) developed the State Soil Geographic (STATSGO) Database. Figure 5 shows the hydrologic soil group for the Grand Basin.

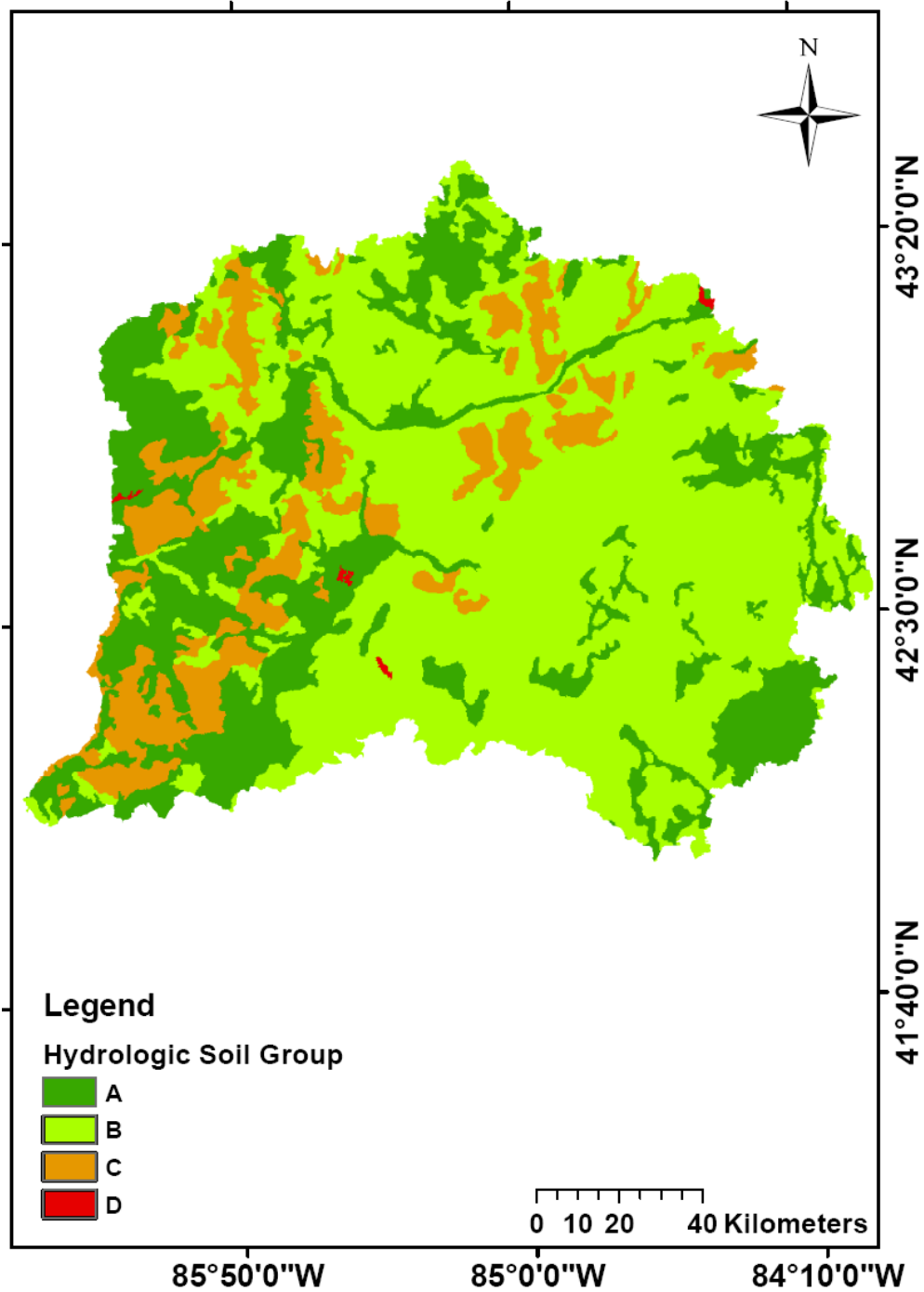


Figure 5. Hydrologic Soil Groups for the Grand Basin

5.0 Climate data

Daily records of precipitation along with minimum and maximum temperatures are obtained from National Climatic Data Center (NCDC). However, relative humidity, wind speed and solar radiation were estimated by the weather generator in the SWAT model. Figure 6 shows the locations of precipitation and temperature gages used for this watershed. As a default approach, the climatic data of a watershed is assigned from the nearest climatic station.

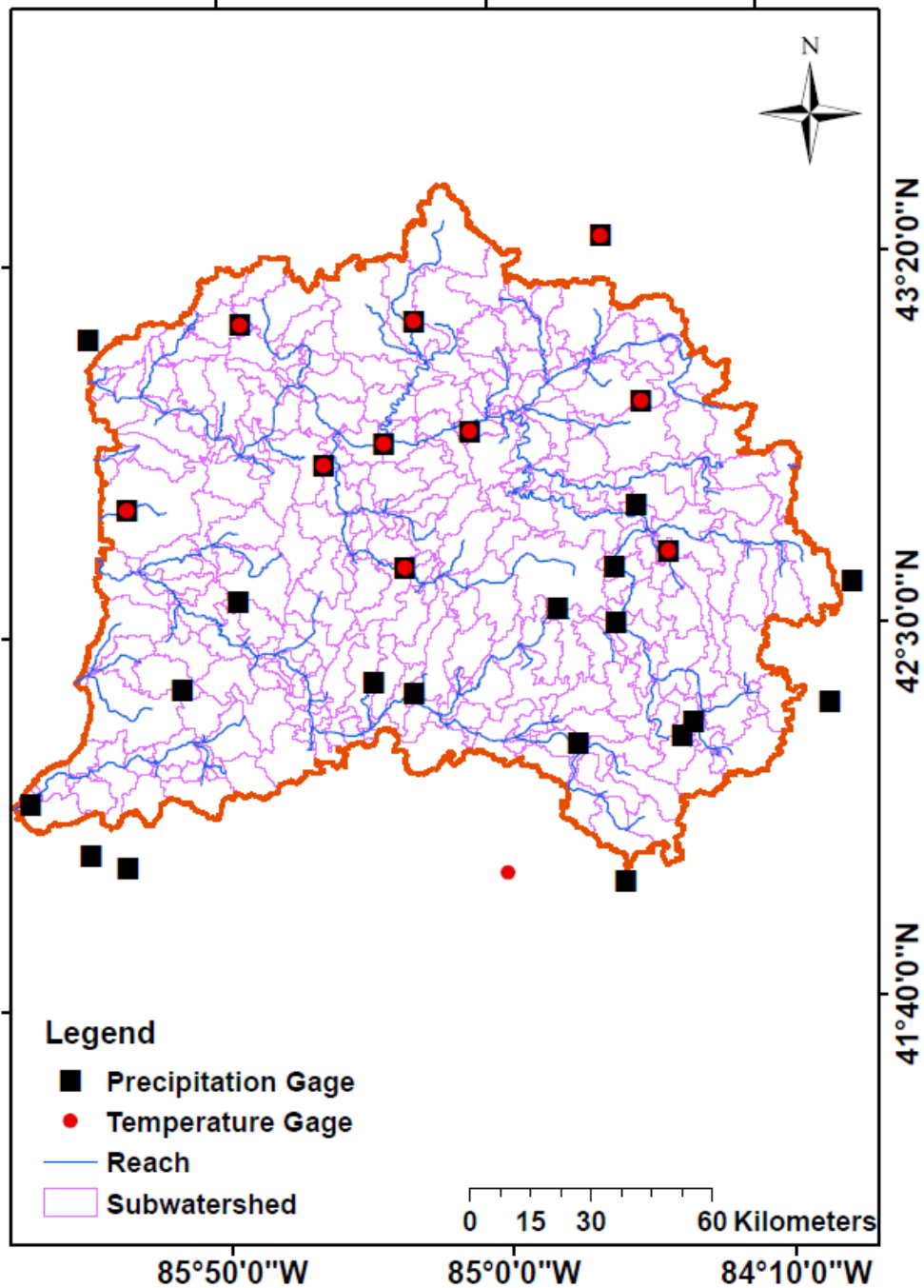


Figure 6. Temperature and precipitation gages in the Grand Basin

6.0 SWAT Model

In this project ArcSWAT 2.1.5a for ArcGIS 9.2 SP6 was used. This version of the SWAT model was released on 7/20/2009. We also used Better Assessment Science Integrating point & Non-point Sources (BASINS v. 4.0 released on 03/2009) to obtain model inputs. Nineteen years of daily precipitation and temperature data (1990 to 2008) were used to setup the model.

6.1 Watershed Delineation

The Digital Elevation Model (DEM 90 m) and USGS National Hydrography Dataset (NHD) were used to delineate the study area. In the case of observing cuts in the stream networks, finer resolution elevation data set (National Elevation Dataset-NED) was employed to correct the inconsistencies within the stream networks. The study area was divided to 330 subwatersheds. Figure 7 shows the boundary and the locations of subwatersheds in the Grand basin.

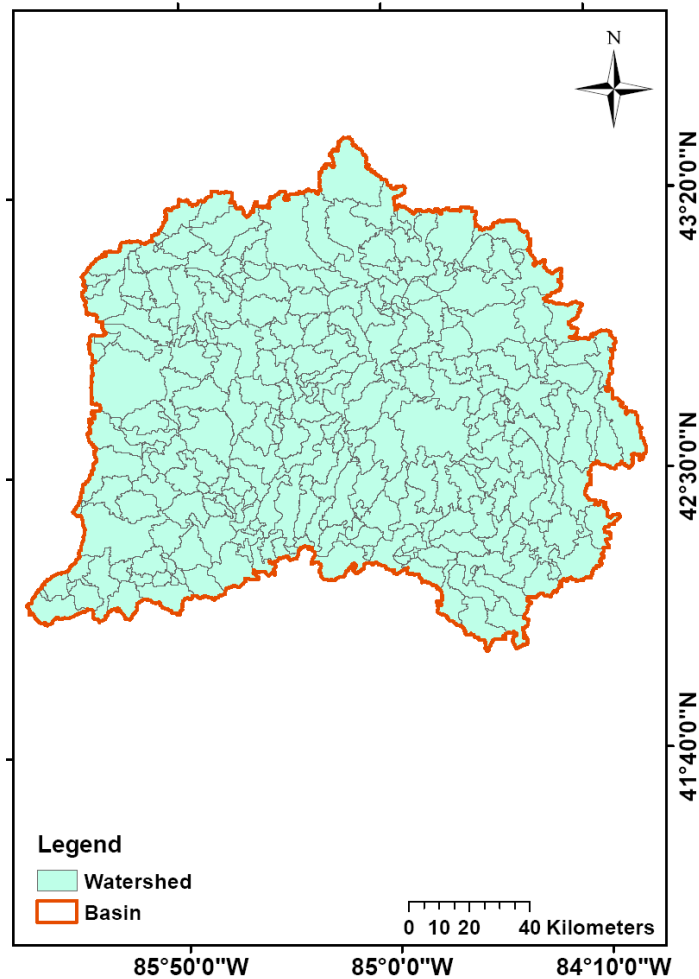


Figure 7. Delineated watersheds of the Grand Basin

The SWAT model generates results on the outlets of subwatersheds. Since our goal is to obtain the model results on the locations of fish sampling points, these points were introduced to the model. In some cases, the fish sampling points lie on small creeks, which are too small for the model to recognize. In those cases, fish sampling points are snapped to the nearest stream network. Therefore, the location of the subbasin outlet sometimes is different from the original location of the fish sampling point (Table 3). Figures 8a and 8b show the locations of the original fish sampling points and the model.

Table 3. Coordinates of the original and snapped fish sampling points

Original	LAT	LONG	Snapped	LAT	LONG
1	41.6960	-86.0534	1	42.1199	-86.4674
2	41.7723	-85.3053	2	42.1488	-86.4087
3	41.7737	-85.3693	3	42.1265	-86.3708
4	41.8293	-86.0142	4	42.1906	-86.3032
5	41.8363	-85.2190	5	42.1697	-86.2576
6	41.8381	-85.1844	6	42.2061	-86.2453
7	41.8481	-86.2663	7	42.1751	-86.2448
8	41.8615	-86.2437	8	42.9039	-86.1824
9	41.8615	-86.2437	9	43.0455	-86.16
10	41.8850	-86.2247	10	42.2122	-86.1427
11	41.8876	-86.1403	11	43.1308	-86.1325
12	41.9012	-86.2175	12	42.6464	-86.1058
13	41.9109	-86.3684	13	43.1599	-86.0884
14	41.9170	-86.2113	14	42.4482	-86.0868
15	41.9395	-86.3238	15	42.2259	-86.071
16	41.9431	-86.1914	16	42.9315	-86.0489
17	41.9574	-86.0292	17	42.1742	-86.0484
18	41.9649	-84.6572	18	43.18	-86.0477
19	41.9691	-86.1822	19	42.6089	-85.9934
20	41.9692	-85.3186	20	42.5119	-85.9889
21	41.9696	-86.3596	21	42.5919	-85.9778
22	41.9776	-86.3590	22	42.6108	-85.9694
23	41.9864	-86.3269	23	43.1797	-85.9469
24	41.9878	-86.1642	24	42.6857	-85.9362
25	42.0000	-86.5189	25	43.1991	-85.9283
26	42.0054	-85.3939	26	42.2649	-85.9262
27	42.0054	-85.3939	27	43.1968	-85.908
28	42.0124	-84.7208	28	42.1914	-85.9051
29	42.0187	-86.1216	29	42.6855	-85.9018
30	42.0220	-85.2423	30	42.2122	-85.8895
31	42.0228	-85.7131	31	42.9773	-85.8765
32	42.0286	-86.5010	32	43.2863	-85.8765
33	42.0321	-84.5032	33	42.5269	-85.8403
34	42.0433	-86.4399	34	42.1968	-85.829

35	42.0508	-84.6352	35	42.6905	-85.8202
36	42.0528	-86.0634	36	42.9662	-85.7995
37	42.0582	-86.4378	37	42.9105	-85.7776
38	42.0638	-85.1596	38	42.4875	-85.771
39	42.0641	-86.3637	39	42.4252	-85.7596
40	42.0649	-86.3567	40	42.4369	-85.7405
41	42.0704	-86.4836	41	42.3545	-85.7399
42	42.0743	-85.1250	42	42.8923	-85.7335
43	42.0757	-84.8345	43	42.9374	-85.724
44	42.0932	-85.2654	44	42.4313	-85.6907
45	42.1031	-85.0350	45	43.1596	-85.6893
46	42.1199	-86.4674	46	43.0838	-85.6845
47	42.1265	-86.3708	47	42.4601	-85.6828
48	42.1273	-84.9071	48	42.8679	-85.6783
49	42.1309	-84.7151	49	43.2614	-85.6779
50	42.1309	-84.7151	50	42.8451	-85.6706
51	42.1311	-84.5000	51	43.1343	-85.6627
52	42.1331	-85.1385	52	43.0219	-85.6624
53	42.1433	-86.2252	53	42.6879	-85.6574
54	42.1488	-86.4087	54	43.0625	-85.6291
55	42.1511	-86.0626	55	43.1767	-85.6118
56	42.1584	-84.9833	56	42.4227	-85.6099
57	42.1651	-84.3795	57	43.1486	-85.5983
58	42.1696	-86.0564	58	42.6589	-85.5967
59	42.1697	-86.2576	59	42.4141	-85.5943
60	42.1742	-86.0484	60	42.4878	-85.5909
61	42.1751	-86.2448	61	42.4069	-85.5899
62	42.1906	-86.3032	62	42.4204	-85.5837
63	42.1914	-85.9051	63	42.3331	-85.5821
64	42.1968	-85.8290	64	43.152	-85.5778
65	42.2047	-84.5079	65	42.2481	-85.5756
66	42.2061	-86.2453	66	43.1065	-85.5705
67	42.2085	-84.6629	67	42.5328	-85.5633
68	42.2122	-86.1427	68	43.1428	-85.5602
69	42.2122	-85.8895	69	42.2837	-85.5419
70	42.2129	-84.3567	70	42.3613	-85.5307
71	42.2185	-84.9027	71	42.5599	-85.4945
72	42.2225	-84.6669	72	42.9605	-85.4827
73	42.2259	-86.0710	73	42.2732	-85.4818
74	42.2305	-84.6201	74	42.8764	-85.4771
75	42.2367	-84.9148	75	42.9556	-85.4755
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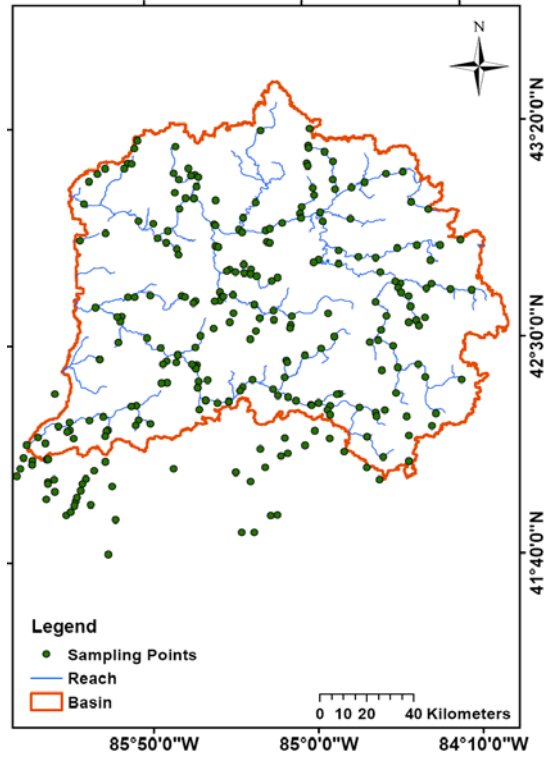
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80	42.2596	-84.9995	80	42.683	-85.4484
81	42.2649	-85.9262	81	42.6819	-85.4418
82	42.2653	-84.9602	82	42.2778	-85.4224
83	42.2653	-84.9602	83	42.7792	-85.4206
84	42.2677	-85.9001	84	42.7854	-85.4063
85	42.2732	-85.4818	85	42.6874	-85.391
86	42.2751	-85.0764	86	42.6172	-85.3905
87	42.2778	-85.4224	87	42.7744	-85.3756
88	42.2778	-85.4224	88	42.3181	-85.3641
89	42.2837	-85.5419	89	42.9381	-85.3528
90	42.2837	-85.5419	90	42.3324	-85.3505
91	42.2907	-85.1165	91	42.8042	-85.3319
92	42.2955	-84.5597	92	42.7708	-85.3307
93	42.2966	-84.8649	93	42.9832	-85.3306
94	42.2970	-85.1688	94	42.3601	-85.2988
95	42.2980	-84.8512	95	42.766	-85.2975
96	42.3148	-86.3198	96	42.7848	-85.2947
97	42.3181	-85.3641	97	42.6489	-85.2815
98	42.3228	-85.1935	98	42.7577	-85.2658
99	42.3324	-85.3505	99	43.041	-85.264
100	42.3331	-85.5821	100	42.5959	-85.2543
101	42.3331	-85.5821	101	43.3175	-85.2301
102	42.3392	-84.2193	102	42.933	-85.2144
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104	42.3539	-84.4065	104	42.8853	-85.1945
105	42.3545	-85.7399	105	42.3228	-85.1935
106	42.3567	-85.5771	106	42.9395	-85.1927
107	42.3601	-85.2988	107	42.6245	-85.1826
108	42.3613	-85.5307	108	42.5885	-85.1811
109	42.3660	-85.1323	109	42.297	-85.1688
110	42.3844	-84.6291	110	42.7506	-85.1571
111	42.3938	-84.5466	111	42.366	-85.1323
112	42.4034	-84.4409	112	42.432	-85.122
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122	42.4465	-86.0864	122	42.2573	-84.9958
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126	42.4601	-85.6828	126	43.3207	-84.9726
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128	42.4772	-84.5675	128	43.0927	-84.9632
129	42.4875	-85.7710	129	43.0638	-84.9576
130	42.4878	-85.5909	130	42.4739	-84.9401
131	42.4943	-84.6880	131	42.9974	-84.9281
132	42.5005	-84.6441	132	42.9635	-84.9161
133	42.5119	-85.9889	133	42.2367	-84.9148
134	42.5157	-85.3061	134	42.2185	-84.9027
135	42.5193	-84.8705	135	42.2537	-84.901
136	42.5269	-85.8403	136	42.6088	-84.8999
137	42.5328	-85.5633	137	43.2303	-84.8971
138	42.5400	-84.6273	138	42.5193	-84.8705
139	42.5467	-85.2761	139	42.2966	-84.8649
140	42.5523	-84.4309	140	43.1217	-84.8582
141	42.5523	-84.4309	141	43.1921	-84.8541
142	42.5553	-85.0981	142	42.298	-84.8512
143	42.5599	-85.4945	143	43.0855	-84.8468
144	42.5661	-84.4829	144	42.7988	-84.8389
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147	42.5729	-84.4437	147	43.0899	-84.7614
148	42.5823	-84.3984	148	42.2438	-84.7506
149	42.5827	-85.4102	149	42.8224	-84.7351
150	42.5885	-85.1811	150	42.4943	-84.688
151	42.5919	-85.9778	151	42.2225	-84.6669
152	42.5929	-84.5974	152	42.2085	-84.6629
153	42.5959	-85.2543	153	42.6471	-84.6519
154	42.5959	-85.2543	154	42.8177	-84.6451
155	42.6008	-85.0881	155	42.5005	-84.6441
156	42.6088	-84.8999	156	42.0508	-84.6352
157	42.6089	-85.9934	157	42.3844	-84.6291
158	42.6108	-85.9694	158	42.54	-84.6273
159	42.6172	-85.3905	159	42.7616	-84.6237
160	42.6245	-85.1826	160	42.2305	-84.6201
161	42.6269	-84.4715	161	42.5929	-84.5974
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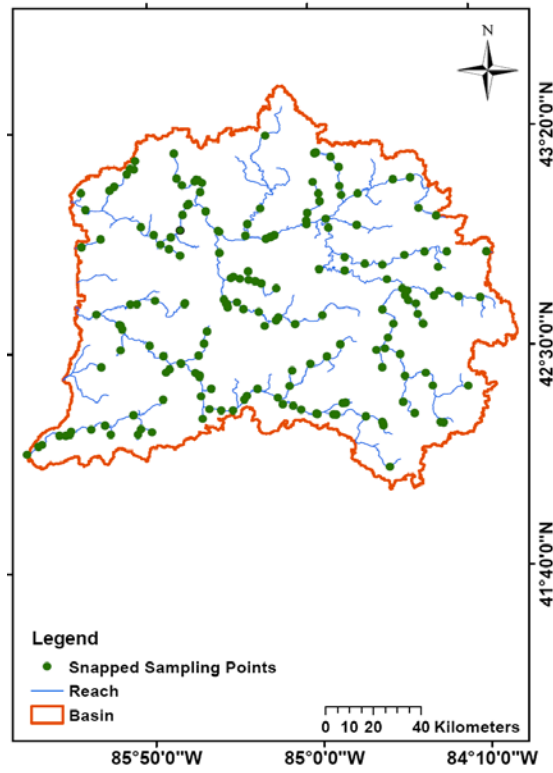
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167	42.6639	-85.4865	167	42.6998	-84.5329
168	42.6659	-85.4598	168	42.8522	-84.5313
169	42.6665	-85.5865	169	42.7168	-84.5211
170	42.6672	-84.4800	170	42.6809	-84.5176
171	42.6809	-84.5176	171	42.2047	-84.5079
172	42.6819	-85.4418	172	43.145	-84.4905
173	42.6830	-85.4484	173	42.5661	-84.4829
174	42.6831	-85.6402	174	42.6672	-84.48
175	42.6832	-84.1515	175	42.6269	-84.4715
176	42.6855	-85.9018	176	43.028	-84.4521
177	42.6857	-85.9362	177	42.5729	-84.4437
178	42.6874	-85.3910	178	42.4034	-84.4409
179	42.6879	-85.6574	179	42.8614	-84.4288
180	42.6891	-84.2618	180	42.3539	-84.4065
181	42.6905	-85.8202	181	42.6945	-84.3864
182	42.6945	-84.3864	182	42.1651	-84.3795
183	42.6989	-85.4583	183	42.9979	-84.3635
184	42.6998	-84.5329	184	42.8024	-84.3607
185	42.7118	-84.3588	185	42.7118	-84.3588
186	42.7168	-84.5211	186	42.2129	-84.3567
187	42.7250	-84.5468	187	42.859	-84.3083
188	42.7386	-85.1886	188	42.6891	-84.2618
189	42.7506	-85.1571	189	42.3392	-84.2193
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191	42.7616	-84.6237	191	42.6832	-84.1514
192	42.7660	-85.2975	192		
193	42.7708	-85.3307	193		
194	42.7744	-85.3756	194		
195	42.7792	-85.4206	195		
196	42.7848	-85.2947	196		
197	42.7854	-85.4063	197		
198	42.7988	-84.8389	198		
199	42.8024	-84.3607	199		
200	42.8042	-85.3319	200		
201	42.8042	-85.3319	201		
202	42.8059	-84.9685	202		
203	42.8156	-84.9414	203		
204	42.8177	-84.6451	204		
205	42.8224	-84.7351	205		
206	42.8451	-85.6706	206		

207	42.8500	-84.8371	207		
208	42.8522	-84.5313	208		
209	42.8590	-84.3083	209		
210	42.8614	-84.4288	210		
211	42.8679	-85.6783	211		
212	42.8724	-85.4633	212		
213	42.8762	-84.2012	213		
214	42.8764	-85.4771	214		
215	42.8853	-85.1945	215		
216	42.8884	-85.2095	216		
217	42.8923	-85.7335	217		
218	42.9039	-86.1824	218		
219	42.9105	-85.7776	219		
220	42.9274	-85.3368	220		
221	42.9315	-86.0489	221		
222	42.9330	-85.2144	222		
223	42.9374	-85.7240	223		
224	42.9381	-85.3528	224		
225	42.9395	-85.1927	225		
226	42.9556	-85.4755	226		
227	42.9604	-85.1269	227		
228	42.9605	-85.4827	228		
229	42.9635	-84.9161	229		
230	42.9662	-85.7995	230		
231	42.9701	-84.7713	231		
232	42.9773	-85.8765	232		
233	42.9781	-85.0284	233		
234	42.9832	-85.3306	234		
235	42.9949	-85.0327	235		
236	42.9974	-84.9281	236		
237	42.9979	-84.3635	237		
238	43.0203	-85.0238	238		
239	43.0219	-85.6624	239		
240	43.0280	-84.4521	240		
241	43.0410	-85.2640	241		
242	43.0455	-86.1600	242		
243	43.0522	-85.4726	243		
244	43.0612	-85.5859	244		
245	43.0612	-85.5859	245		
246	43.0625	-85.6291	246		
247	43.0638	-84.9576	247		
248	43.0838	-85.6845	248		
249	43.0855	-84.8468	249		

250	43.0899	-84.7614	250		
251	43.0927	-84.9632	251		
252	43.1065	-85.5705	252		
253	43.1090	-84.6922	253		
254	43.1217	-84.8582	254		
255	43.1308	-86.1325	255		
256	43.1343	-85.6627	256		
257	43.1400	-84.5789	257		
258	43.1428	-85.5602	258		
259	43.1450	-84.4905	259		
260	43.1486	-85.5983	260		
261	43.1486	-85.5983	261		
262	43.1520	-85.5778	262		
263	43.1596	-85.6893	263		
264	43.1599	-86.0884	264		
265	43.1767	-85.6118	265		
266	43.1770	-84.9866	266		
267	43.1797	-85.9469	267		
268	43.1800	-86.0477	268		
269	43.1876	-84.9919	269		
270	43.1921	-84.8541	270		
271	43.1968	-85.9080	271		
272	43.1991	-85.9283	272		
273	43.2303	-84.8971	273		
274	43.2460	-84.9799	274		
275	43.2460	-84.9799	275		
276	43.2560	-84.9821	276		
277	43.2562	-85.8932	277		
278	43.2614	-85.6779	278		
279	43.2863	-85.8765	279		
280	43.3175	-85.2301	280		
281	43.3207	-84.9726	281		



(a)



(b)

Figure 8. Maps of the original fish sampling points (a) and the model's outlets (b).

6.2 Monitoring Stations

The model was calibrated on a monthly basis for flow, sediment, total nitrogen, and total phosphorus. Five years of data were used for calibration, including 80 observations for each water quality constituent.

The most downstream USGS gaging station on the Grand River (Station No. 04119000) was used to calibrate the model for flow (Figure 9). Water quality data were obtained from the EPA Storage and Retrieval (STORET) database for the Macomb station (700123) on the Grand River (Figure 10). Since no flow data was available at the location of water quality observations, discharge from the USGS gage had to be extrapolated to the downstream STORET point.

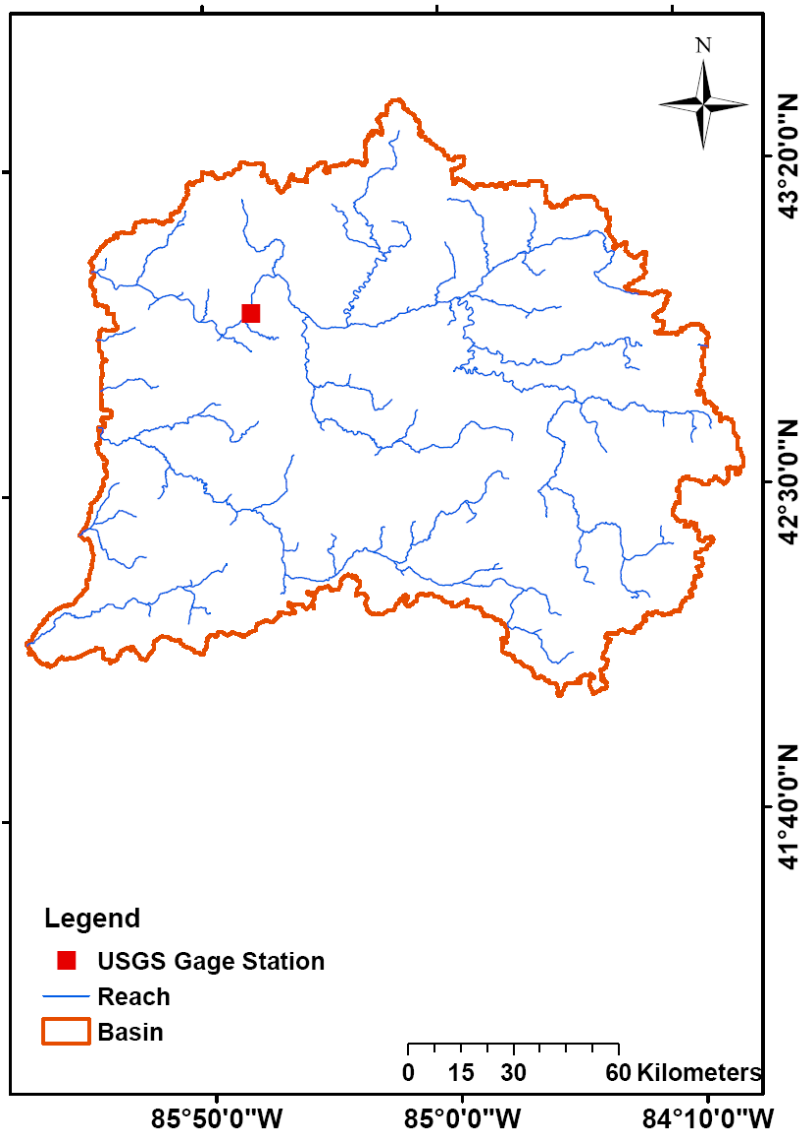


Figure 9. The delineated watersheds and selected USGS station.

In order to scale the flow data, the watershed was first calibrated using daily flow data, then the SWAT output was used to extrapolate the flow for the STORET water quality sample point. The scaled flow and daily water quality data were input to the USGS Load Estimator model (LOADEST) in order to generate monthly average values that were used for the final model calibration.

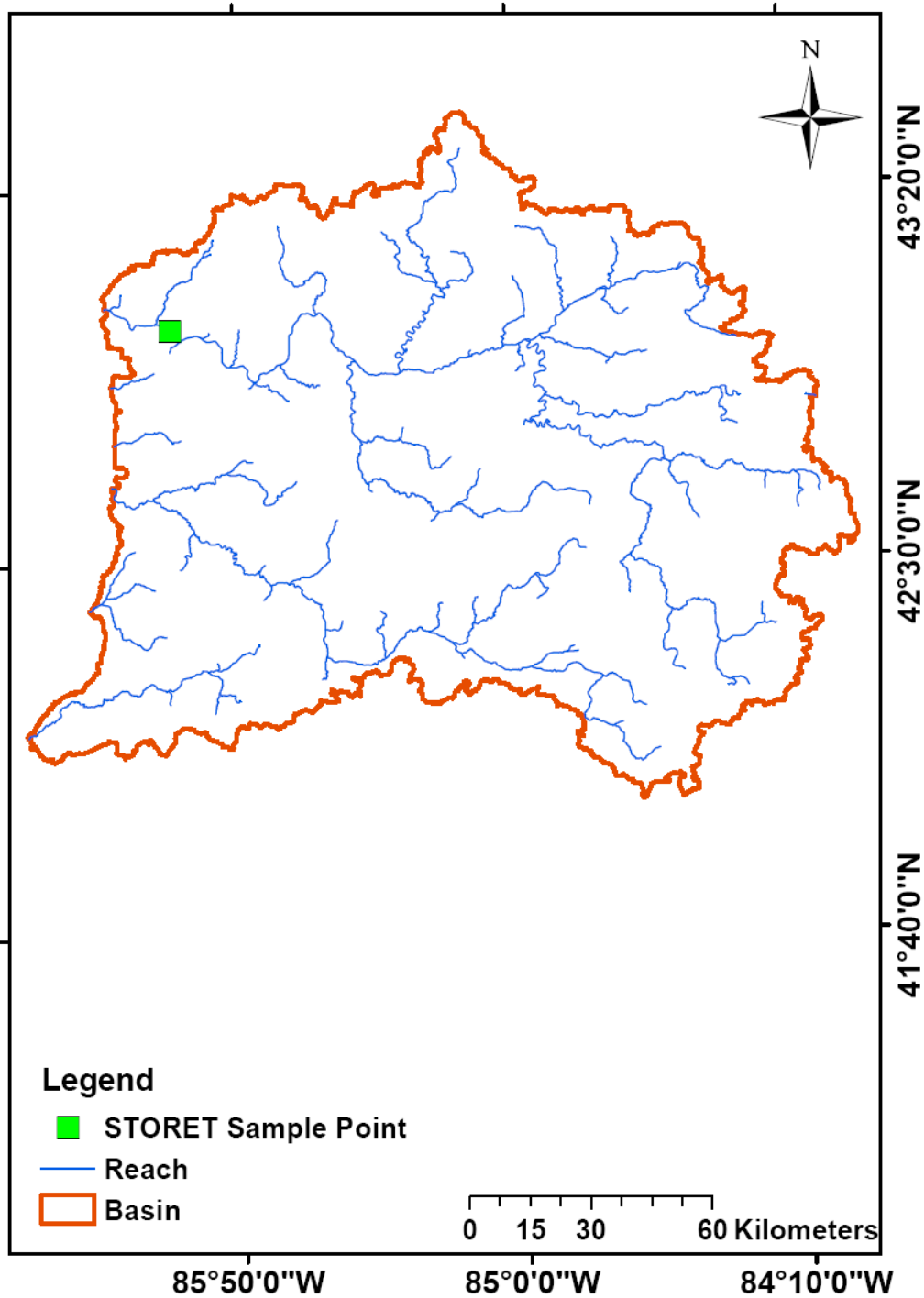


Figure 10. STORET sampling location used to calibrate water quality parameters

6.3 Model Calibration

In the next step, the sensitivity analysis was performed. The Latin- Hypercube One-At-a-Time (LH-OAT) method was employed using observed flow, sediment, total nitrogen, and total phosphorus data (van Griensven, Meixner et al. 2006). The sensitivity ranking of 42 parameters for this watershed is given in Table 4.

Table 4: Rank-Based Sensitivity Analysis*

	Flow	Sed	TotalN	TotalP
Alpha_Bf	1	1	2	2
Cn2	2	2	5	4
Ch_K2	3	5	3	3
Rchrg_Dp	4	7	9	10
Esco	5	10	7	7
Timp	6	8	6	6
Sol_Awc	7	15	4	5
Sol_Z	8	14	11	8
Gwqmn	9	17	17	14
Canmx	10	18	15	15
Surlag	11	11	1	1
Blai	12	9	13	11
Ch_N2	13	3	14	16
Epco	14	21	20	20
Biomix	15	12	16	12
Gw_Delay	16	23	21	25
Smtmp	17	19	12	13
Gw_Revap	18	24	27	26
Slope	19	16	19	18
Sol_K	20	27	23	19
Ssubbsn	21	22	18	17
Revapmn	22	28	25	42
Sol_Alb	23	26	22	24
Nperco	24	25	8	22
Spcon	42	4	42	42
Usle_P	42	6	10	9
Spexp	42	13	42	42
Usle_C	42	20	24	23
Phoskd	42	29	26	21
Pperco	42	30	28	27
Ch_Cov	42	42	42	42
Ch_Erod	42	42	42	42
Sftmp	42	42	42	42
Shallst_N	42	42	42	42
Smfmn	42	42	42	42
Smfmx	42	42	42	42
Sol_Labp	42	42	42	42
Sol_No3	42	42	42	42
Sol_Orgn	42	42	42	42
Sol_Orgp	42	42	42	42
Tlaps	42	42	42	42

* Each number represents the relative important of each parameter for a given objective, with 1 being most important and 42 being virtually no impact.

In the next step, the model was calibrated based on the results obtained from the sensitivity analysis and observed values from the monitoring stations. The Nash and Sutcliffe coefficient of efficiency, along with the root mean square error (RMSE), and the coefficient of determination (R^2) were used for the model evaluation. The results of this section are presented in Table 5, 6 and figures 11 to 18.

The calibrated model has achieved excellent comparisons with observed flow and sediment. The comparisons of sediment were not as good because the observed data did not provide enough information. However, the model is still able to give proper predictions on the same magnitude with the observed data.

Table 5. Statistics of model calibration

	Nash-Sutcliffe	RMSE	R^2
Flow	0.421	9.16	0.518
Total Suspended Solids (TSS)	0.542	47.28	0.587
Total N	0.616	2759.95	0.670
Total P	0.546	135.78	0.572

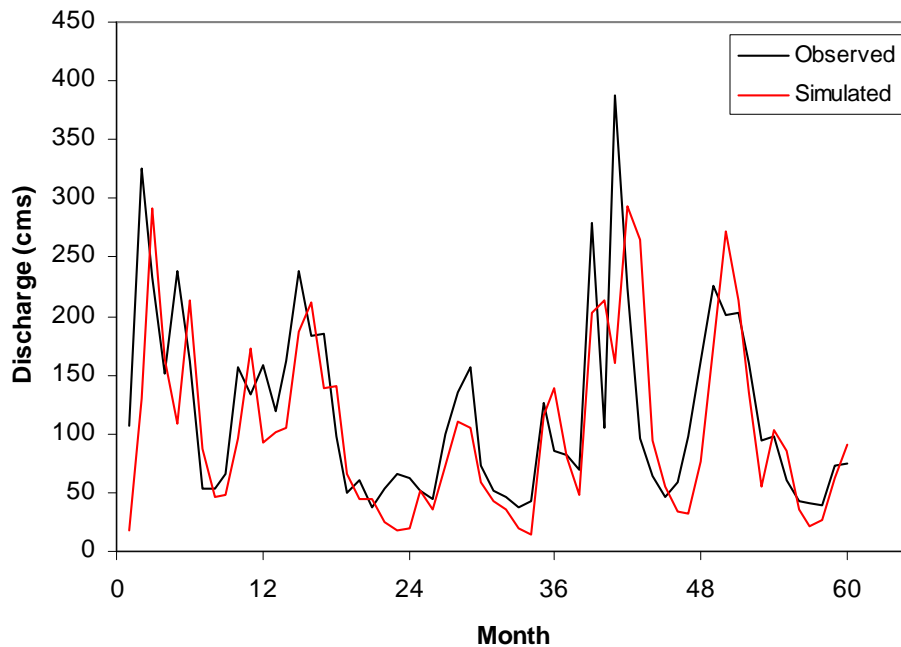


Figure 11. Model simulated results vs. scaled observed flow at STORET Station 700123

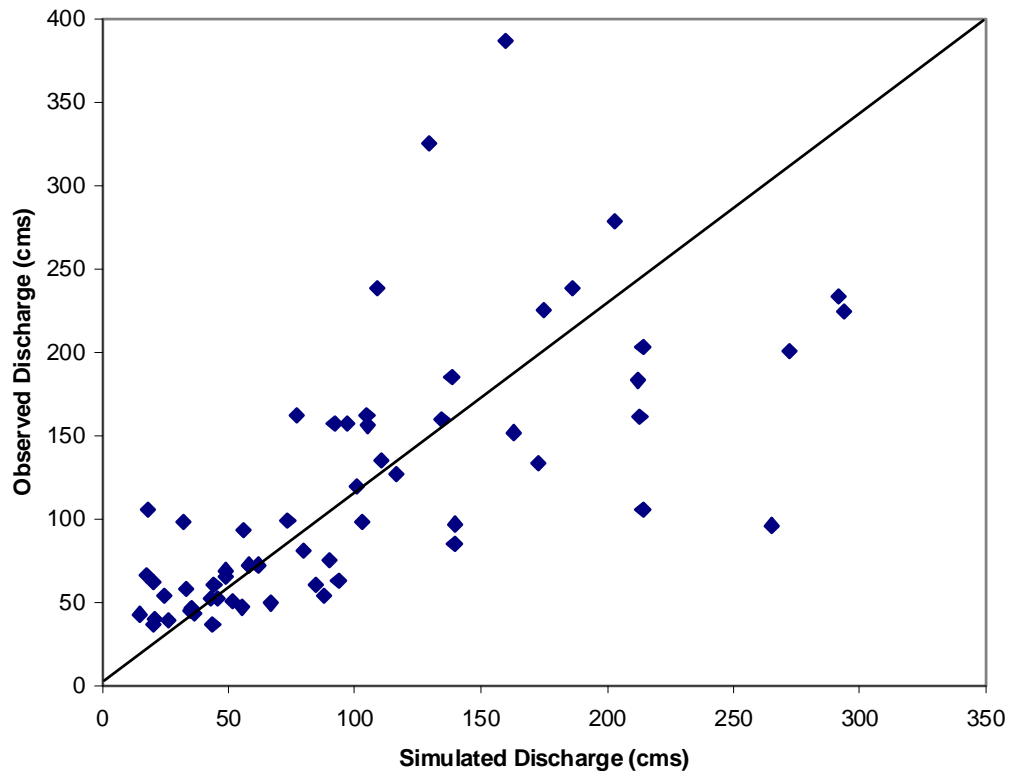


Figure 12. Simulated vs. scaled observed flow at STORET Station 700123

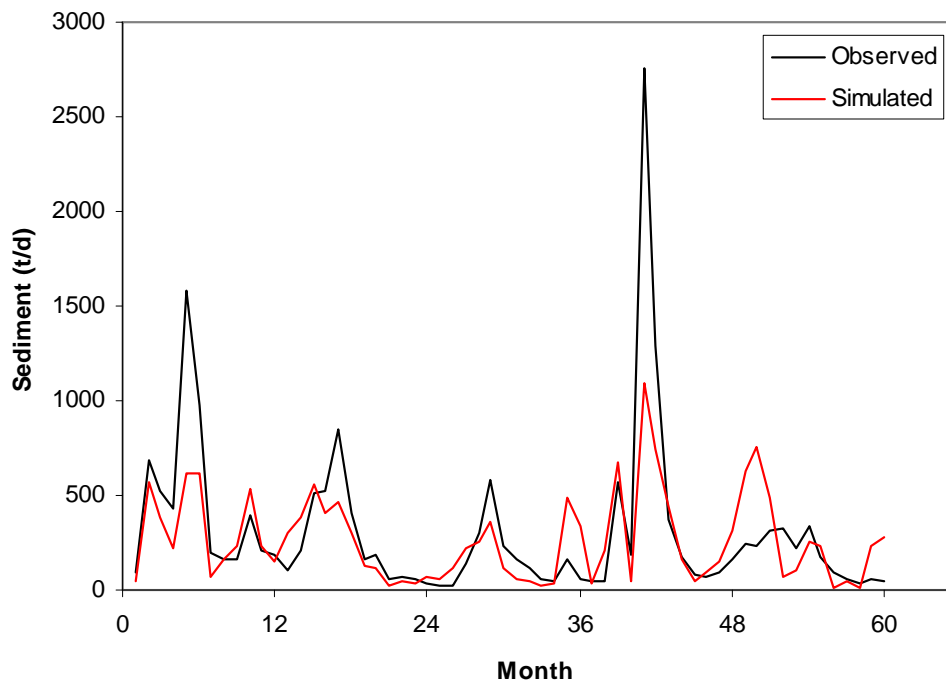


Figure 13. Time series of simulated vs observed TSS

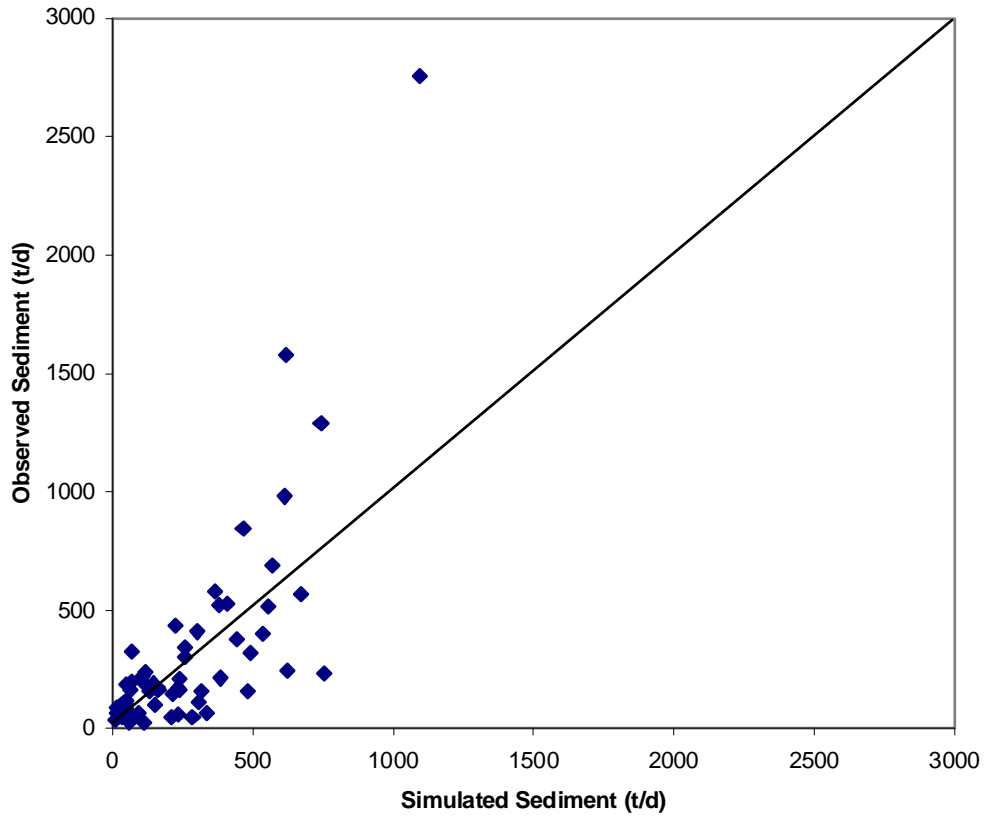


Figure 14. Simulated vs observed TSS

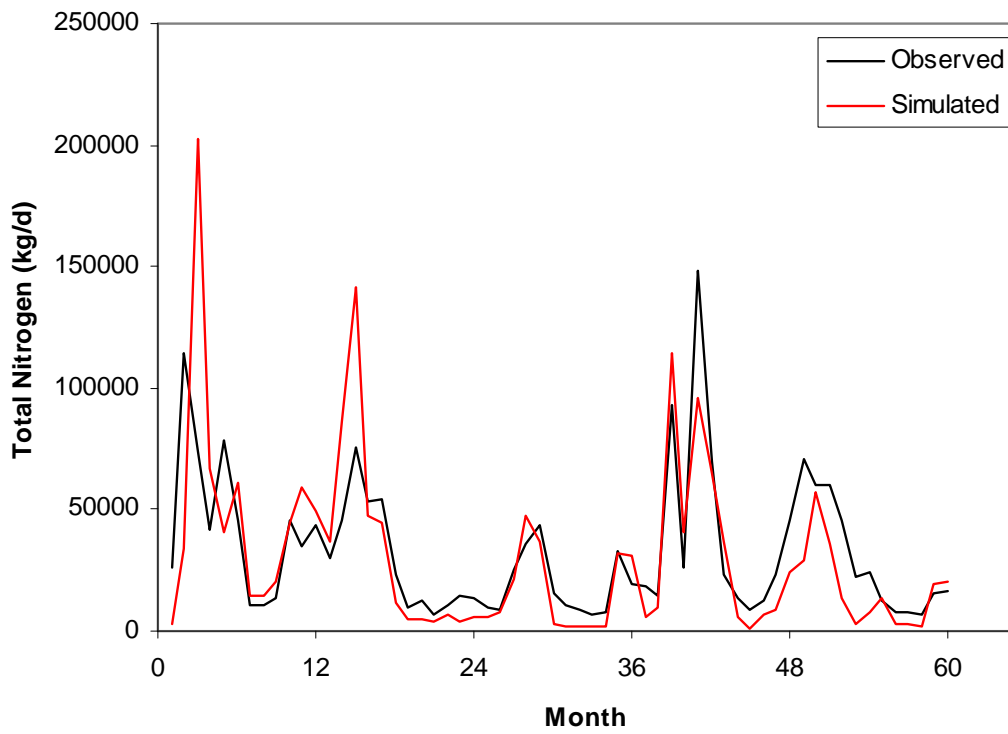


Figure 15. Time series of simulated vs observed Total Nitrogen

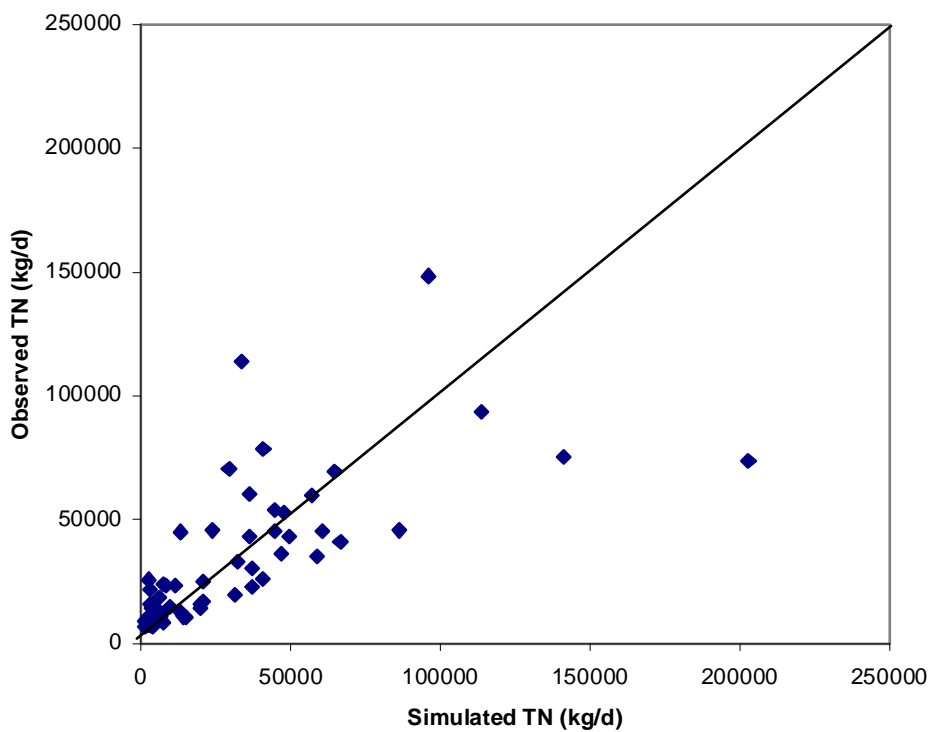


Figure 16. Simulated vs observed Total Nitrogen

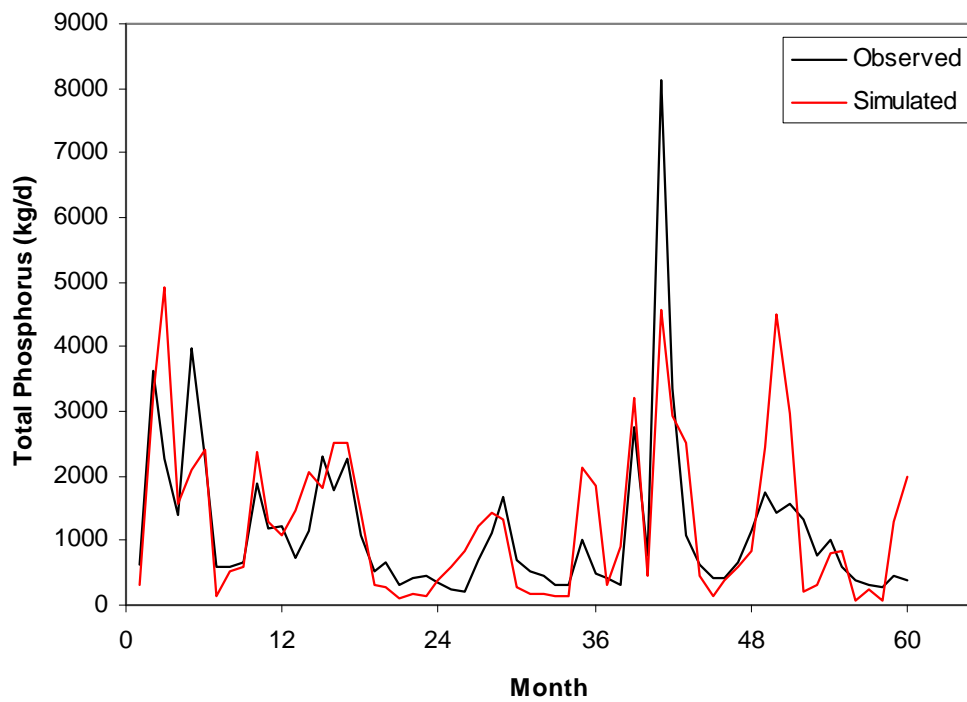


Figure 17. Time series of simulated vs. observed total phosphorus

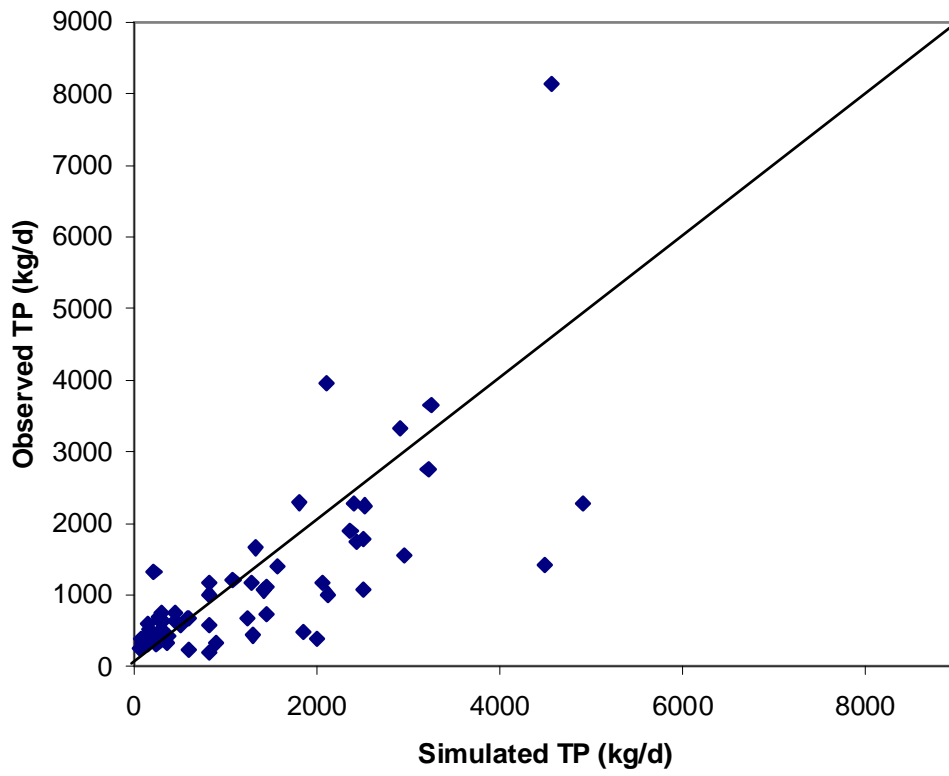


Figure 18. Simulated vs. observed total phosphorus

Table 6. Monthly and annual hydrologic budget for the Grand Basin

Month	Rain	Snowfall	Surface Runoff	Lateral Flow	Total Water Yield	ET	Sediment Yield	PET
	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(t/ha)	(mm)
1	65.4	39.97	24.58	0.11	31.86	8.9	0.36	14.41
2	48.49	28.06	30.58	0.08	35.79	13.75	0.45	21.52
3	54.99	19.85	32.76	0.23	41.69	39.34	0.56	60.45
4	80.18	3.92	16.29	0.3	27.37	61.12	0.28	103.12
5	97.5	0	20.3	0.32	30.72	75.14	0.44	137.57
6	88.01	0	17.79	0.26	25.84	94.49	0.28	168.71
7	88.03	0	11.5	0.24	16.76	101.61	0.14	178.14
8	87.8	0	10.02	0.26	13.51	66.41	0.13	146.25
9	88.48	0	15.34	0.29	18.98	46.43	0.2	120.3
10	81.62	0.62	13.57	0.32	19.12	41.55	0.17	76.73
11	83.41	11.12	17.99	0.33	25.86	26.8	0.23	43.03
12	61.88	36.57	17.95	0.16	26.53	14.48	0.21	22.53
Annual Average	925.79	140.11	228.67	2.9	314.03	590.02	3.45	1092.76

6.4 Impacts of Landuse Changes (Pre-Settlement vs. Current) on Water Budget and Water Quality

In this stage of study, the landuse circa 1800 county base (LU1800) was used to setup the SWAT model for the pre-settlement (PS) scenario. Then the model was run for the period of 1990-2008 and the results were compared with the model results obtained based on the current landuse map (NLCD 2001). Results are presented in figures 18 to 27 **Error! Reference source not found.** and Table 7. In addition, in order to compare the results from two different scenarios, percent difference was calculated. Percent change is the numerical interpretation of comparing one value with another (Equation 1). The equation for determining the percent difference is used to compare the change to the average of the two values (Equation 2).

$$\text{Percent change} = \frac{(x_1 - x_2)}{x_2} \times 100 \quad (1)$$

$$\text{Percent difference} = \frac{(x_1 - x_2)}{(x_1 + x_2)/2} \times 100 \quad (2)$$

The results are presented based on the average annual simulated values for the period of study (1990-2008).

Table 7. Annual average percent changes (1800 vs. current) for the Grand Basin

Calibrated	Current	Pre-Settlement	Percent Change	Percent Difference
Recharge (mm)	98.41	206.75	-52.40%	-71.01%
Surface Runoff (mm)	225.01	121.92	84.55%	59.43%
Baseflow (mm)	85.25	175.18	-51.33%	-69.06%
Water Yield (mm)	313.15	300.71	4.14%	4.05%
Sediment Yield (t/ha)	3.44	0.14	2374.93%	184.47%
Total N Output (t/ha)	16.32	2.72	499.77%	142.84%
Total P Output (t/ha)	1.92	0.07	2759.50%	186.48%

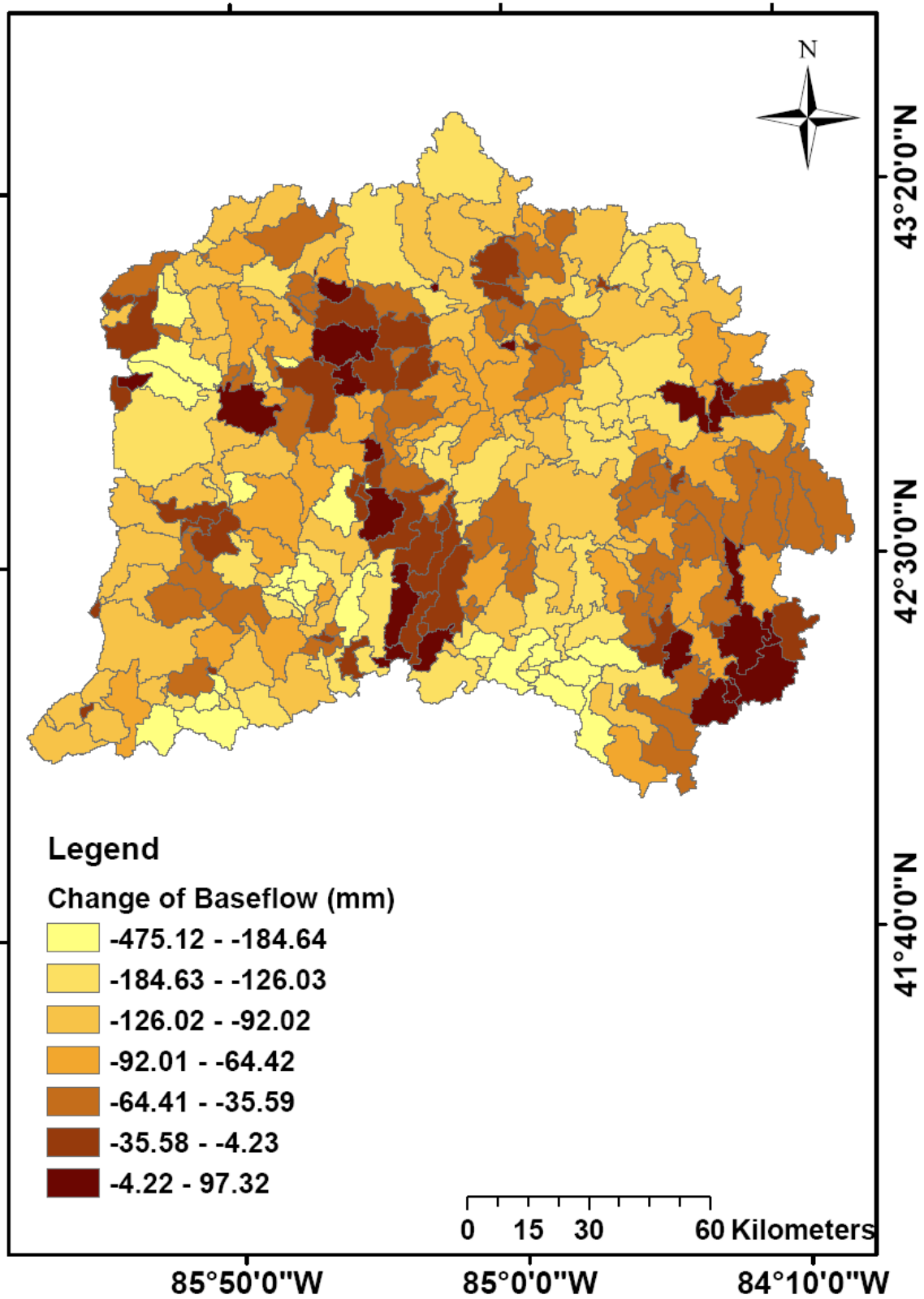


Figure 18. Change of baseflow values resulted from landuse changes (mm)

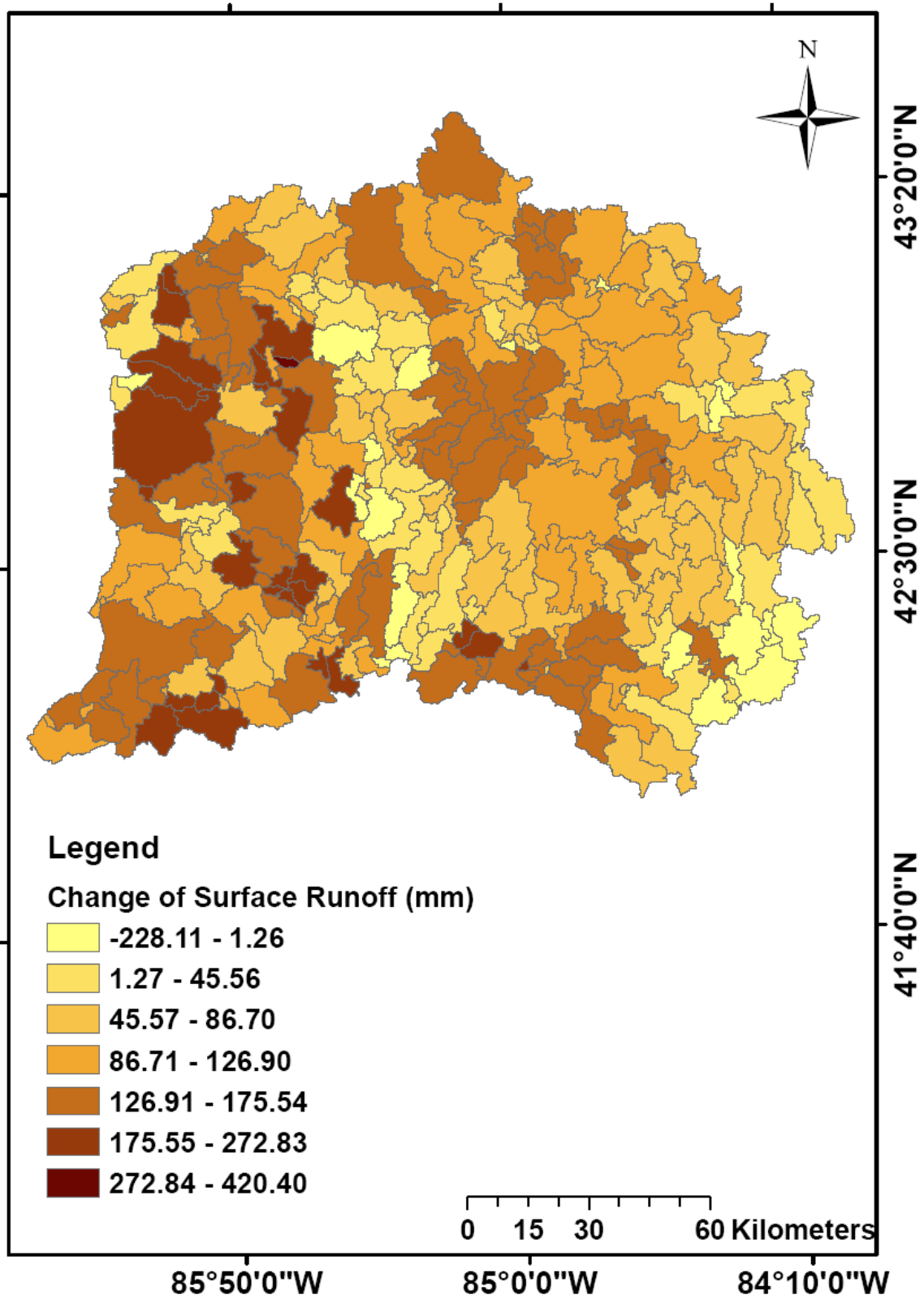


Figure 19. Change of surface runoff values resulted from landuse changes (mm)

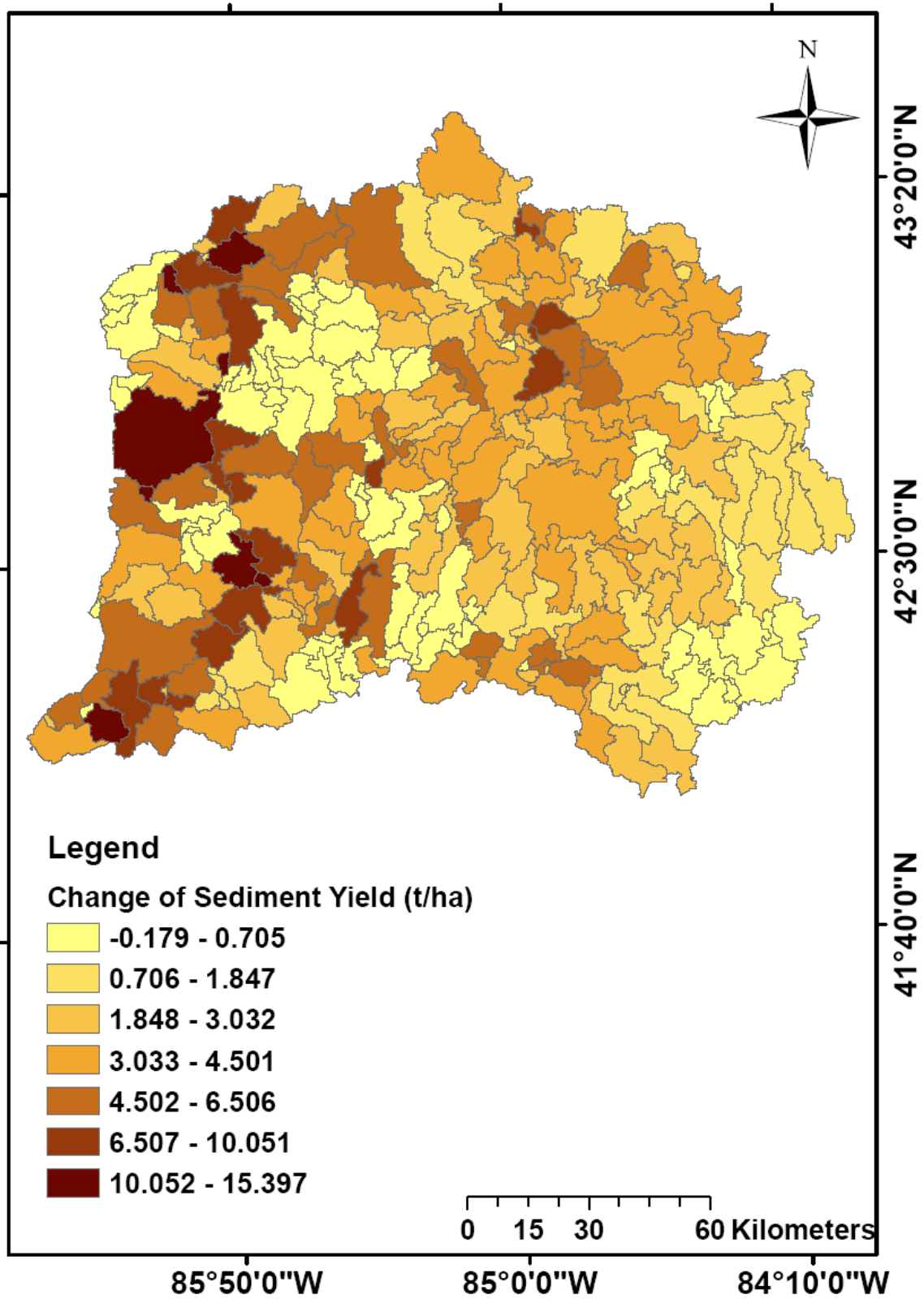


Figure 20. Change of sediment yields resulted from landuse changes (t/ha)

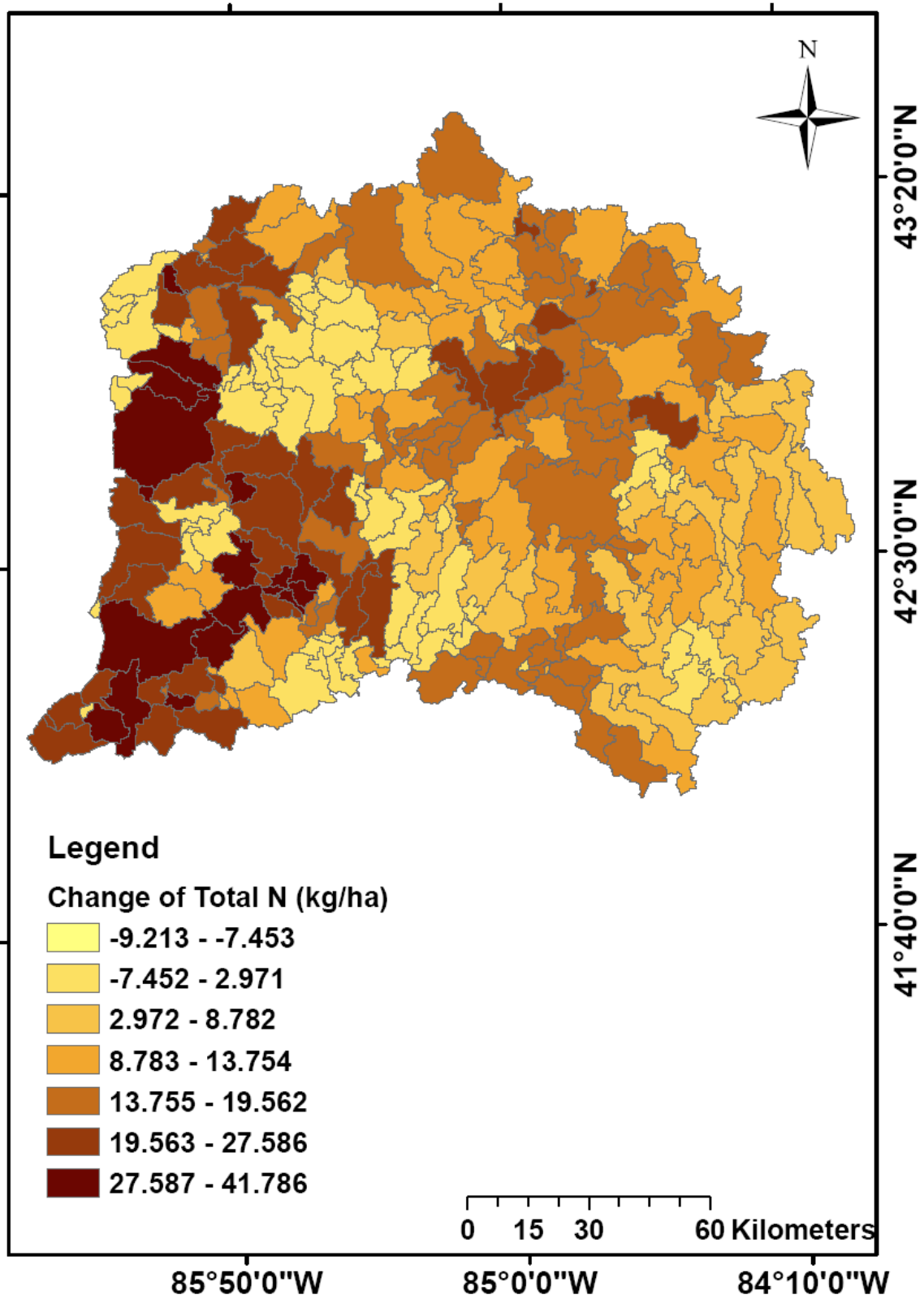


Figure 21. Change of total N output values resulted from landuse changes (kg/ha)

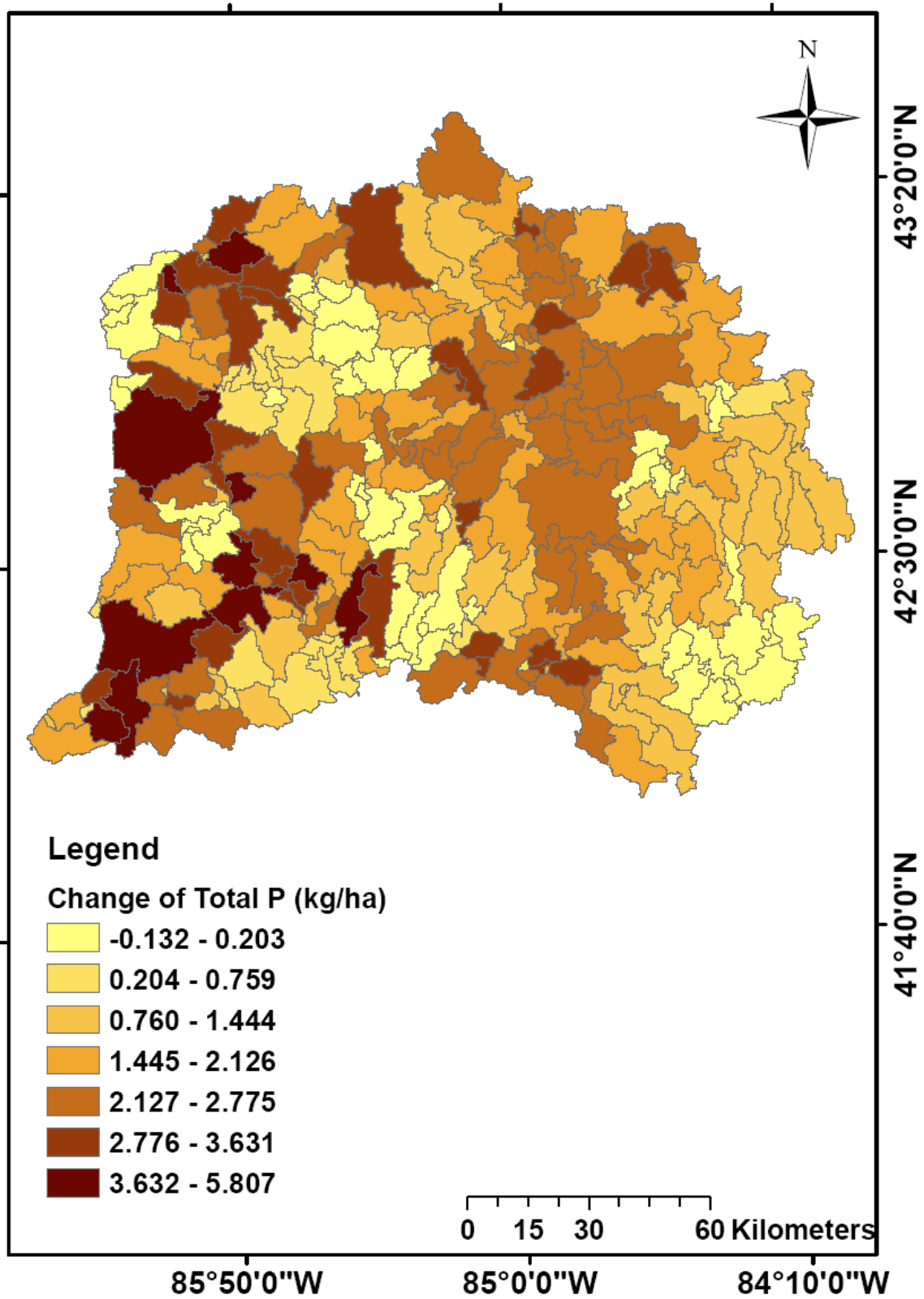


Figure 22. Change of total P output values resulted from landuse changes (kg/ha)

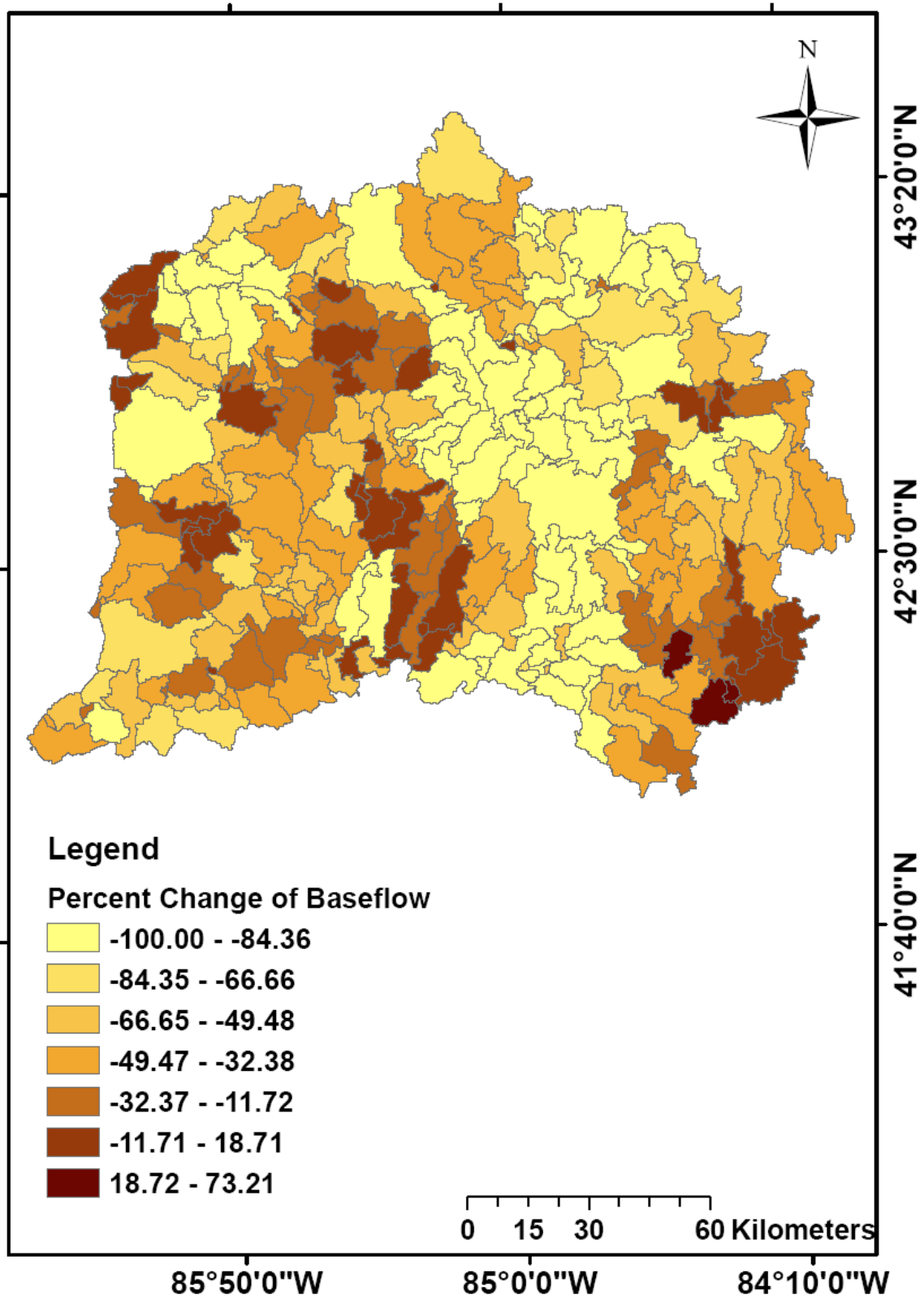


Figure 23. Percent change of baseflow values resulted from landuse changes

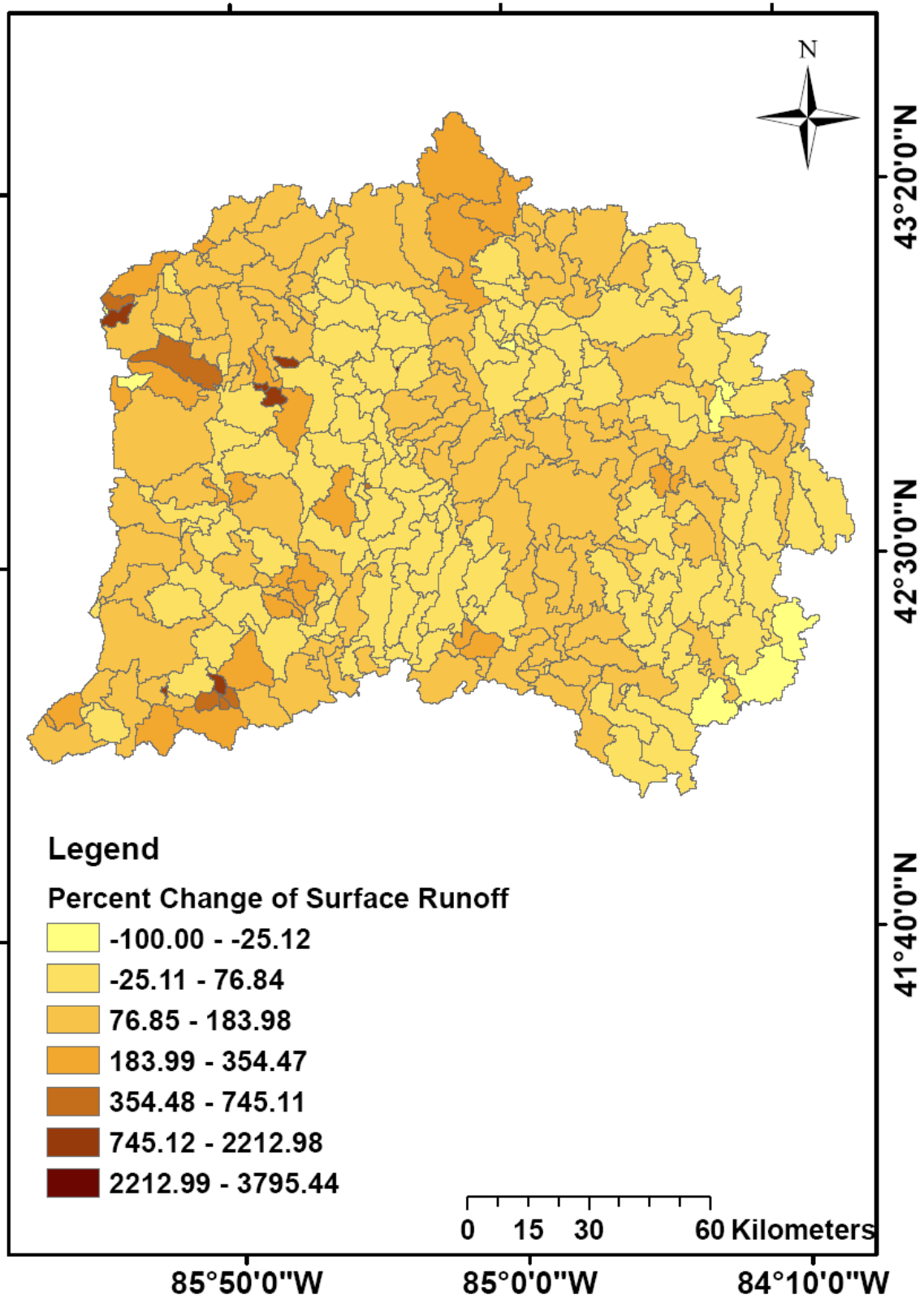


Figure 24. Percent change of surface runoff values resulted from landuse changes

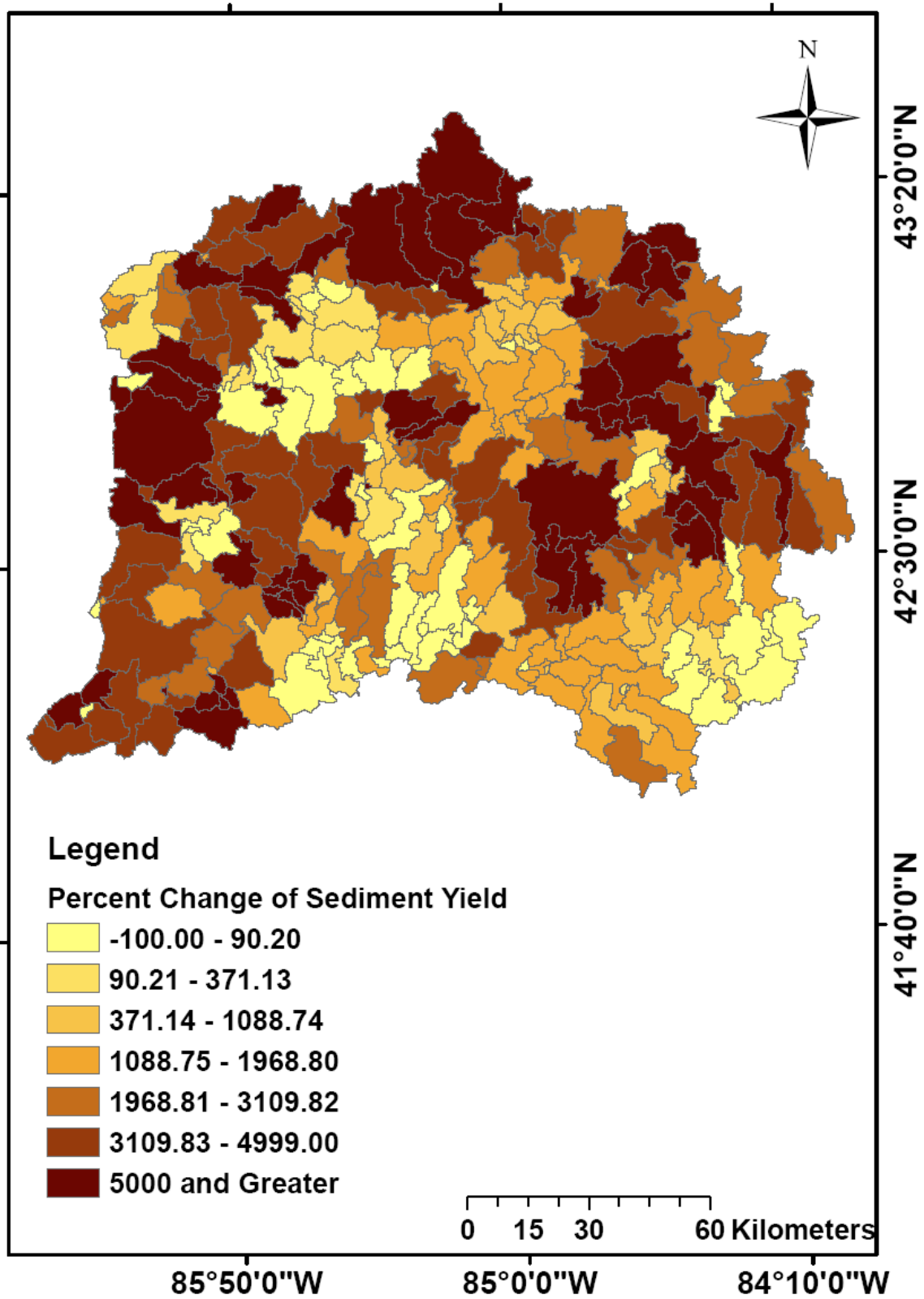


Figure 25. Percent change of sediment yield resulted from landuse changes

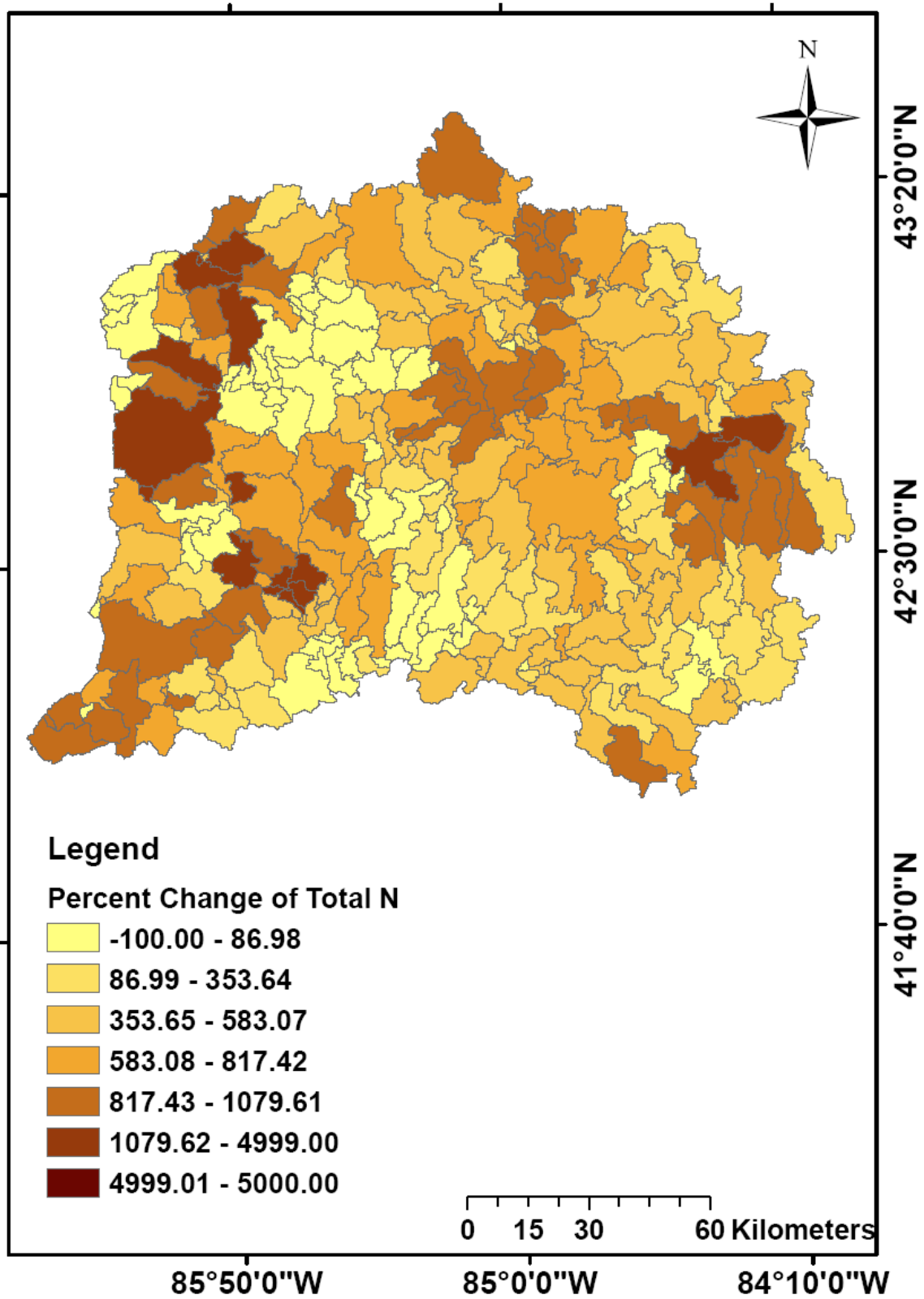


Figure 26. Percent change of total N output values resulted from landuse changes

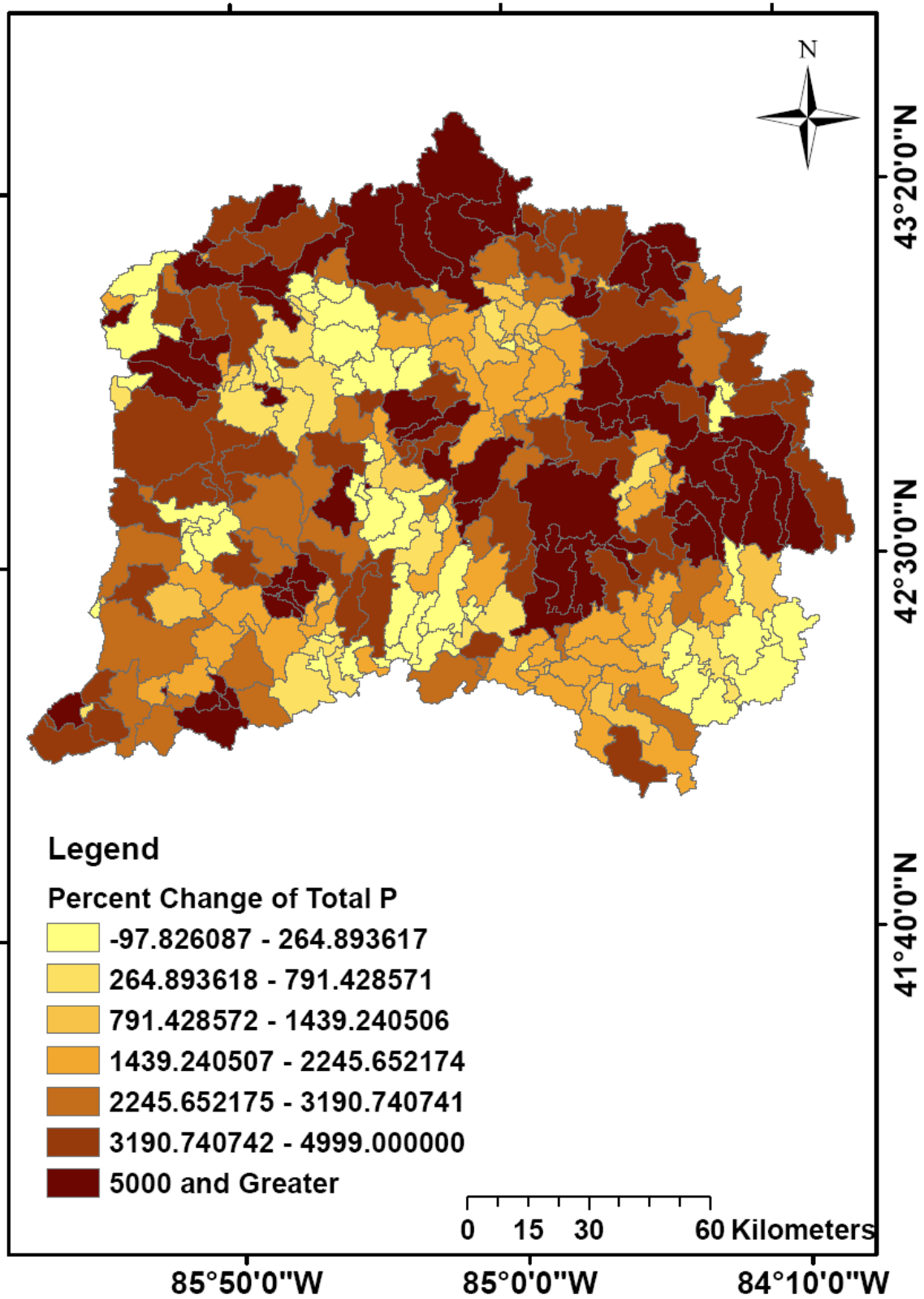


Figure 27. Percent change of total P output values resulted from landuse changes

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8.0 References

van Griensven, A., T. Meixner, et al. (2006). "A global sensitivity analysis tool for the parameters of multi-variable catchment models." Journal of Hydrology **324**: 10-23.