Hydrologic Information Extraction Using Arc Hydro Tool and Dem Isabela, Philippines

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***Abstract*—** Digital Elevation Model (DEM) is used to determine terrain attributes and geomorphologic attributes. The geographic information system and the Arc Hydro tool are used to extract various hydrologic information and to describe various characteristics of the catchment area. The procedure includes the: DEM reconditioning and stream network generation. Extracted hydrologic information is essential for hydrologic analysis and to provide support for water resource management.

***Keywords*—** Digital Elevation Model, Hydrologic Information, Arc Hydro.

INTRODUCTION

The Digital Elevation Model (DEM) is a three-dimensional (XYZ) digital cartography dataset created from contour lines or photogrammetric methods. The altitudes of the terrain are taken at regular horizontal intervals from ground points. DEMs can be represented in one of two ways: (1) as a raster or (2) as a vector (Triangular Irregular Network, TIN). (Gandhi and Sarkar, 2016) A digital elevation model (DEM) is a vertical datum referenced bare-earth raster grid. A bare-earth elevation model with applications in hydrology, soil science, and land use planning. 2018 (GISGeography). More applications have focused on employing DEM to carry out topography and geomorphologic study in recent years. With the advancement of GIS technology, DEMs are increasingly being employed in geographic information systems, and watershed feature extraction is becoming more widely used. (Ma, et al., 2008; Jing, et al., 2010)

Arc Hydro is a geospatial data model, specifically a GIS for water resources, that was created to facilitate hydrologic modeling and analysis by synthesizing geographic and temporal water resources data. Arc Hydro techniques are used to create numerous data sets that collectively characterize the drainage patterns of a watershed (Zhang et al., 2010). Data on flow directions, flow accumulation, stream definition, stream segmentation, and watershed delineation are generated using raster analysis. These data are used to create a vector representation of drainage lines and catchments. A geometric network is built using this information. Applying Arc Hydro tools to produce features that may be used in hydrologic modeling demonstrates their utility.(ESRI, 2011)

The study focused on the use of geographic information systems (GIS) to manage and use geospatial data. The hydrologic features within the different delineated watersheds within the Province of Isabela will be extracted using the Arc Hydro tool using an ArcGIS for future hydrologic model research.

Study Site

The Province of Isabela, the Philippines' second largest province, is located on the northeastern coast of the island of Luzon, the largest of the 7,107 islands that make up the Philippine archipelago. It is the largest province on Luzon Island, with a total land area of 10, 655 square kilometers.

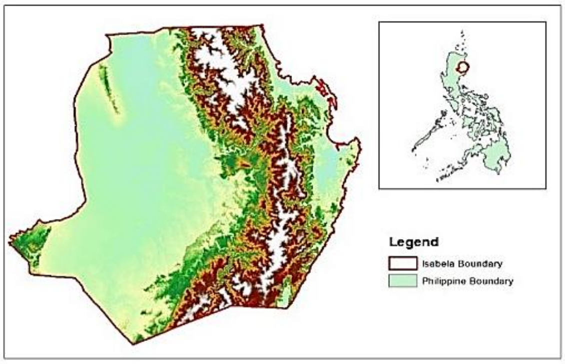

Figure 1: *Study site*

METHODOLOGY

To recondition the digital elevation model and generate data on flow direction, flow accumulation, streams, stream segments, and watersheds, geoprocessing was used. The following information will be used to create a vector representation of catchments and drainage lines based on selected points for network analysis. Detailed information on the landscape's connectivity and watersheds will be established in order to provide richer data that can be utilized to compute watershed parameters typically used in hydrology and resource analysis.

Raster analysis, watershed and stream network delineation, for example, is best done in the same projected spatial reference system (or projection). Slope, length, and area must all be calculated, and these should be done in linear (not geographic) units to match the elevation units.

To extract watershed features and produce the necessary demarcated watersheds for future hydrologic model study, the arc hydro tool was employed. The approach involves DEM preprocessing, stream network construction, and watershed boundary generation (Zhang et al., 2010).

Terrain Preprocessing

Terrain preprocessing performs the terrain initial analysis of and prepares the dataset for further processing. A DEM of the study is required as a source of information for terrain preprocessing in order to determine the surface drainage pattern The DEM and its derivatives can be utilized for effective watershed delineation and stream network development once they have been preprocessed. Potential difficulties with the terrain representation can be recognized during preprocessing, avoiding DEM mistakes from spreading to subsequent phases of the investigation. A good preprocessing indicates that the underlying DEM is free of serious flaws that will obstruct further analysis. Because all parameters can be altered, the initial basin delineation performed during preprocessing has no bearing on later basin processing (save for performance during the extraction stage). (Shamsi, 2008)

Stream Network Generation

Once the DEM was satisfactorily edited, the flow direction grid, stream grid, catchment, and adjoint catchment can be delineated. The flow direction is computed based on a presented grid. The direction of the steepest descent from the cell is indicated by the values in the flow direction grid's cells. To process a DEM with known sinks, the function flow direction with sinks can be used instead. The flow direction for a grid with sinks ensures that all cells within a sink watershed flow into the sink point of the watershed.

The flow accumulation was calculated for each cell in the input grid using a grid that holds the cumulative number of cells upstream of that cell. The flow accumulation raster identifies the contributing area at each cell in the domain, which is an extremely important quantity in many hydrologic analyses. The flow accumulation grid and the threshold were used to define a stream. In the stream grid, the cells in the input flow accumulation grid with a value larger than the threshold are assigned a value of 1. All other cells have no data allocated to them.

The river threshold is set to a preset value. The number indicates 1% of the maximum flow accumulation, which is the suggested stream determination threshold. Preprocessed data is prepared using streams to help speed up point delineation. There is no requirement that the streams be useful or reflective of current streams. The threshold can be set to any other value. A lower threshold will result in a denser stream network and, in most cases, a greater number of delineated catchments, which will slow down delineation. Each cell in the catchment grid has a value (grid code) that indicates which catchment the cell belongs to.

The value is the value carried by the stream segment or sinks link that drains the region and is defined in the input stream segment link (Stream segmentation) or sink link grid (sink segmentation). The catchment polygon was processed once the catchment grid was delineated. In order to process the drainage line, the input stream link grid must be converted into a drainage line feature class using the stream segmentation method. The identification of the catchment in which the feature class is located is printed on each line of the feature class. The drainage line feature class is generated by the function flow direction with streams, which is based on the input stream feature class. Each delineated catchment's drainage sites can likewise be processed and associated with the catchments. The outflow point can be used to describe the watershed, which includes all points upstream of it.

RESULTS AND DISCUSSION

The DEM was reconditioned to guide drainage towards the vector information on stream position. It's only recommended if the vector stream data is more dependable than the raster DEM data.

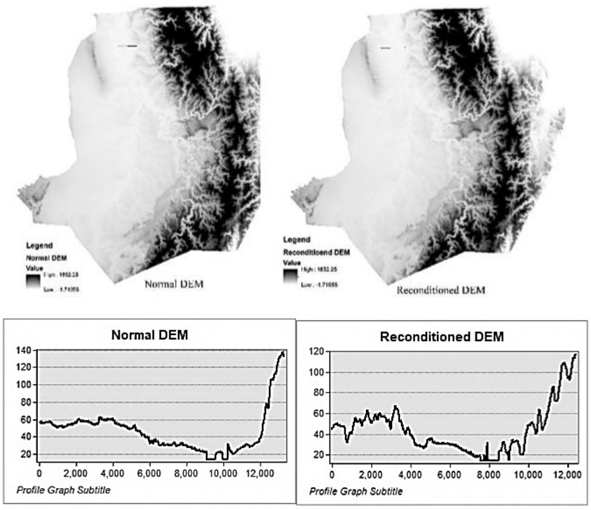

Figure 2: *Profiles of cross-section for the normal DEM and reconditioned DEM*

Depending on the quality of the initial DEM, reconditioning and filling sinks may not be necessary. Modifying the elevation data in the DEM to make it more consistent with the input vector stream network is called reconditioning. The lowest elevation of the DEM is -1.71055 and the highest elevation is 1852.25. Profile cross-sections for the normal DEM and reconditioned DEM were examined using ArcGIS 3D analyst to show the elevation as shown in Figure 2.

Stream Network Generation

To ensure that the flow of water will be moved towards the outlet all the depressions were filled using the "fill sink" function. As a result of the flow direction as shown in Figure 3 the values indicated represent eight possible directions of the flow or the direction of flow from the upstream going to the outlet point can be determined.

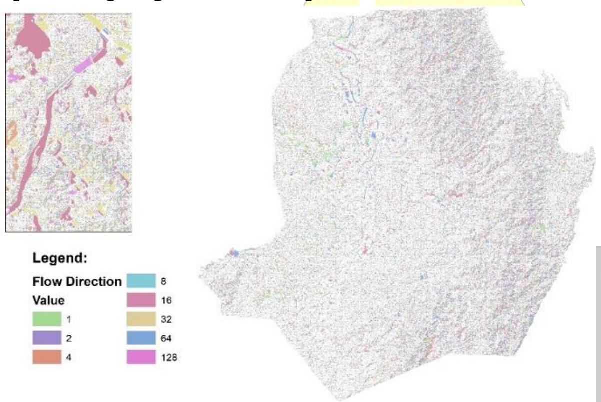

Figure 3: *Flow direction*

The flow direction output was used to create the flow accumulation using the "flow accumulation" function, see figure 4. The flow accumulation could be used to determine the contributing area and how much rain has fallen within a catchment.

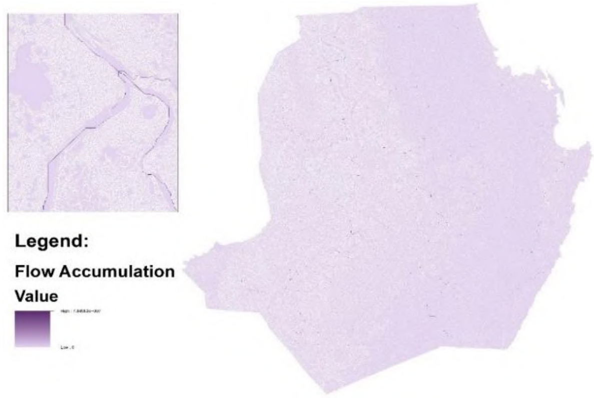

Figure 4: *Flow Accumulation*

Extracted network and catchment, the color of the stream network, and the Hydro ID of the catchment, as shown in Figure 5 associated with the attribute table as shown in table 1 and table 2, respectively. The generated information in the attribute table is the shape length, slope, a change in elevation from upstream to downstream, and length of the flow path. This information can be used to calculate the concentration time of each catchment and other information that can be used for hydrologic analysis.

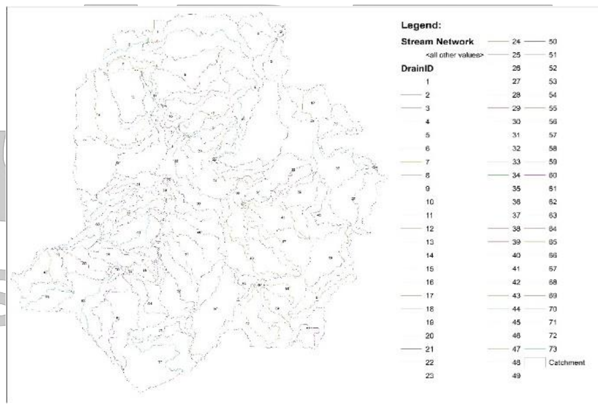

Figure 5: *Stream Network and Catchment*

Table 1: *Stream Netwok*

DrainID	Shape Length (m)	Slope	ElevUP (m)	ElevDS (m)	LengthDown (m)	LongestFL (m)
1	11401.80808	0.004399	63.290493	13.130968	11401.80808	11401.80808
2	7319.970414	0.065026	475.993408	0	7319.970414	7319.970414
3	53487.13921	0.034223	1845.131348	14.623836	60929.73373	53487.13921
4	17548.87048	0.072543	1343.85022	70.798691	24207.62769	17548.87048
5	18929.40872	0.091331	1799.082397	70.240082	25588.16593	18929.40872
6	20969.94696	0.011627	258.454071	14.623836	28414.61254	20969.94696
6	20969.94696	0.011681	259.577362	14.623836	28414.61254	20969.94696
7	21965.21607	0.011928	277.154785	15.13717	46022.39174	21965.21607
8	44099.03605	0.033637	1498.501465	15.13717	68154.14065	44099.03605
9	59545.98264	0.025717	1549.422363	18.063837	103374.4299	59545.98264
10	34062.01982	0.006001	220.843964	16.420504	63831.176	34062.01982
11	20961.47978	0.001933	56.947407	16.420504	50728.5649	20961.47978

12	20839.12914	0.041136	858.653564	1.39791	20839.12914	20839.12914
13	13475.27525	0.003377	63.571812	18.063837	57305.79362	13475.27525
14	9178.412331	0.00568	72.869987	20.730505	59310.66735	9178.412331
15	17184.47402	0.003496	80.807739	20.730503	67314.65797	17184.47402
16	28804.06997	0.02906	858.379944	21.317169	88063.29071	28804.06997
17	29086.0191	0.032717	972.93219	21.317169	88347.31091	29086.0191
18	65384.61179	0.004318	314.138489	31.802397	120050.3802	65384.61179
19	62006.53134	0.001941	152.172485	31.802397	116674.3708	62006.53134
20	41263.6955	0.036583	1538.770508	29.191021	120816.3809	41263.6955
21	23162.63202	0.045119	1045.090332	0	23162.63202	23162.63202
21	23162.63202	0.044959	1041.380005	0	23162.63202	23162.63202
22	25691.37877	0.003418	115.357834	27.530504	89773.04684	25691.37877
23	33049.93829	0.022455	769.675354	27.530504	97133.67743	33049.93829
24	1759.446968	0.019651	63.766537	29.191021	81314.20341	1759.446968
25	64512.02341	0.024915	1636.516113	29.191021	144878.0288	64512.02341
26	4902.325394	0.055276	272.857513	1.872	4902.325394	4902.325394
27	32596.14103	0.033328	1096.348877	9.967186	34923.87227	32596.14103
28	36457.62336	0.007347	270.259521	2.402666	38783.28353	36457.62336
29	4245.670631	0.009943	71.022247	28.805326	88223.11827	4245.670631
30	10948.05699	0.004098	73.732841	28.865999	96717.81956	10948.05699
30	10948.05699	0.004101	73.774323	28.865999	96717.81956	10948.05699
31	27910.38418	0.001256	63.935017	28.865999	113682.2178	27910.38418
31	27910.38418	0.001247	63.679817	28.865999	113682.2178	27910.38418
31	27910.38418	0.001226	63.106445	28.865999	113682.2178	27910.38418
32	30483.48122	0.018123	581.657104	29.191021	110847.4155	30483.48122
33	25815.58187	0.037355	1091.921021	127.579956	150819.1557	25815.58187
34	28456.53642	0.001549	82.551491	38.466667	128149.7827	28456.53642
35	52248.90545	0.002101	148.273712	38.466667	151940.0807	52248.90545
36	30952.74962	0.003508	137.456299	28.865999	114928.1262	30952.74962
37	14647.30627	0.019121	348.967743	68.896538	127886.94	14647.30627
38	12240.49386	0.035894	478.13736	38.765007	119255.3044	12240.49386
39	27014.75972	0.040589	1226.209839	129.701141	152016.2625	27014.75972
40	66690.46966	0.019745	1346.806152	30	173703.2091	66690.46966
41	36654.04038	0.00143	81.923874	29.5	130442.4025	36654.04038
42	4595.904037	0.018161	152.366272	68.896538	117833.4667	4595.904037
43	33826.32393	0.035315	1270.19751	75.600952	149350.4047	33826.32393
44	31990.88237	0.001571	84.465302	34.200001	134722.8902	31990.88237
45	15170.73773	0.002286	68.890305	34.200001	117904.8167	15170.73773
46	37852.55806	0.004648	205.474075	29.5	131642.9913	37852.55806
47	50687.83943	0.02666	1426.981689	75.600952	166213.9912	50687.83943
47	50687.83943	0.026554	1421.605347	75.600952	166213.9912	50687.83943
48	39202.03028	0.025858	1105.739136	92.016739	70958.87153	39202.03028
49	37455.57321	0.037203	1485.511719	92.016739	69214.48553	37455.57321
50	9205.691552	0.004801	79.981743	35.784531	123313.2438	9205.691552
50	9205.691552	0.004806	80.029221	35.784531	123313.2438	9205.691552
50	9205.691552	0.004953	81.381287	35.784531	123313.2438	9205.691552

51	27614.75972	0.006907	226.471756	35.719997	141720.2409	27614.75972
52	39267.88814	0.005793	265.384796	37.905151	158917.8267	39267.88814
53	17986.02777	0.004786	124.000786	37.905151	137638.0374	17986.02777
54	26412.56672	0.001777	87.3685	40.412121	153140.6485	26412.56672
55	16017.85497	0.004977	120.139046	40.412121	142743.8657	16017.85497
55	16017.85497	0.004944	119.613365	40.412121	142743.8657	16017.85497
55	16017.85497	0.004937	119.506271	40.412121	142743.8657	16017.85497
56	10967.41774	0.002465	75.849098	48.806667	157481.9184	10967.41774
57	56259.44369	0.015613	995.895203	117.461166	209831.5893	56259.44369
58	28498.20164	0.002394	131.64064	63.413219	184643.6377	28498.20164
59	10431.73232	0.002781	74.892685	45.879696	151017.9278	10431.73232
60	57772.64174	0.002214	176.758881	48.806667	204289.2134	57772.64174
61	36933.77126	0.034458	1272.67041	0	36933.77126	36933.77126
62	35481.54255	0.001541	116.637459	61.938076	191624.9075	35481.54255
63	16557.25576	0.034655	691.263184	117.461166	170131.4725	16557.25576
64	24307.71391	0.008556	253.870148	45.879696	164895.9804	24307.71391
65	40238.14247	0.011174	528.512024	78.867111	216364.6167	40238.14247
66	48596.9859	0.024697	1389.220581	188.984375	215536.6355	48596.9859
66	48596.9859	0.024685	1388.647461	188.984375	215536.6355	48596.9859
67	5456.086937	0.066523	551.571167	188.612335	172395.7365	5456.086937
68	21627.27668	0.048742	1256.569824	202.39769	192650.3787	21627.27668
69	20733.68325	0.045184	1139.229248	202.39769	191754.7142	20733.68325
70	26917.77488	0.010312	356.427643	78.829651	203042.1781	26917.77488
71	35701.49204	0.010195	441.894318	77.887207	235229.5323	35701.49204
72	26394.00287	0.034799	926.434875	7.926586	26394.00287	26394.00287
73	43374.00033	0.011353	570.323242	77.887207	242904.1117	43374.00033

Table 2: *Catchment Characteristics*

HydroID	MinElev	MaxElev	Shape Length (km)	Shape Area (sq km)	Drain Area (sq km)
1	13.130968	165.9749	47.14	33.4417	7850.4809
2	1.22E-09	1075.705	25.84	14.3859	227.3471
3	14.623835	1852.247	147.26	328.7586	328.7586
4	70.86045	1851.215	64.48	113.5245	113.5245
5	70.86045	1800.269	60.68	99.4367	99.4367
6	14.623835	260.816	119.88	116.4156	7488.2806
7	15.137169	297.1696	82.44	61.5761	7122.3285
8	15.137169	1540.85	127.86	249.5365	249.5365
9	18.063837	1849.402	158.42	252.8718	252.8718
10	16.420503	348.3538	105.9	198.6653	198.6653
11	16.420503	70.98375	80.96	36.2179	6862.0871
12	1.39791	1117.912	79.16	120.2778	120.2778
13	18.063837	84.33128	39.08	15.7923	6572.9974
14	20.730503	77.0669	28.8	14.7762	768.5271
15	20.730503	92.55602	63.5	36.481	5788.678
16	21.317169	923.9368	90.42	72.0992	5648.7944

17	21.317169	1108.088	80.52	103.4026	103.4026
18	37.128768	347.9255	182.84	344.8267	344.8267
19	37.128768	171.6478	211.26	408.9242	408.9242
20	29.19102	1651.85	116.22	120.7919	120.7919
21	0	1249.723	74.12	92.5458	92.5458
22	27.530504	116.6112	104.06	110.1457	2929.2384
23	27.530504	769.6754	122.04	117.6257	2647.4568
24	29.19102	78.26804	6.02	0.8749	2409.0392
25	29.19102	1812.113	187.02	521.2213	521.2213
26	1.871999	272.8575	12.78	2.5877	733.6378
27	9.967185	1231.787	97.82	159.1042	159.1042
28	2.402666	1142.459	118.26	225.7557	571.9459
29	28.865999	74.87333	21.34	4.099	2679.4812
30	28.865999	89.54744	42.74	21.9029	2396.2593
31	28.865999	86.73959	112.74	81.8992	279.1229
32	29.19102	581.6571	123.96	149.9171	1886.943
33	157.022384	1231.04	78.36	128.4388	128.4388
34	38.466667	88.39075	115.6	78.9093	78.9093
35	38.466667	150.4884	169.12	118.3144	118.3144
36	28.865999	137.4563	106.76	139.6115	139.6115
37	72.722259	603.9141	49.08	50.735	285.2527
38	30	496.4797	45.48	33.1621	676.7449
39	157.022384	1228.323	73.02	106.0789	106.0789
40	30	1358.486	167.06	290.0734	1060.281
41	29.5	87.05889	152.36	100.2331	2185.6566
42	72.722259	169.8877	18.18	3.4197	358.3301
43	76.900169	1270.198	102.64	149.3996	149.3996
44	34.2	88.82955	113.88	134.2144	134.2144
45	34.2	94.47905	65.84	31.3329	1951.2091
46	29.5	231.62	132.38	188.6998	188.6998
47	76.900169	1600.546	138.78	205.5108	205.5108
48	95.671981	1365.175	89.42	137.0758	137.0758
49	95.671981	1600.585	99.18	209.1144	209.1144
50	35.719997	84.46004	30.9	14.485	1785.1117
51	35.719997	226.8601	94.64	134.7645	134.7645
52	37.905151	301.15	127.94	195.0817	195.0817
53	37.905151	126.6239	81.2	40.4835	1575.545
54	40.41212	94.1081	103	91.3833	91.3833
55	40.41212	121.9292	66.58	43.3076	1443.6782
56	48.806667	91.73511	38.46	17.8214	589.0837
57	117.493331	1075.713	144.52	328.8802	328.8802
58	62.140876	145.6793	100.82	114.2768	114.2768
59	45.879695	79.87663	36.78	12.0379	1277.5924
60	48.806667	117.3663	169.58	274.1406	676.4708
61	1.61E-09	1500.853	97.5	111.2749	111.2749
62	62.140876	177.9834	171.22	195.0981	456.9855

63	117.493331	742.7641	55.7	41.9663	441.3274
64	45.879695	264.7445	89.04	122.7782	122.7782
65	78.924247	539.7989	118.26	150.8168	150.8168
66	188.712615	1395.016	128.02	212.1022	212.1022
67	188.712615	633.977	19.32	8.4663	187.2589
68	215.163635	1558.216	61.74	87.3709	87.3709
69	215.163635	1334.173	64.98	91.4217	91.4217
70	78.924247	476.163	78.92	111.0706	111.0706
71	78.401908	447.3286	94.84	87.3451	87.3451
72	7.926586	1278.569	74.46	107.046	107.046
73	78.401908	1013.164	129.88	314.9851	314.9851

CONCLUSION

All the delineated catchment within the Province of Isabela was selected as the study area. The generated information could provide watershed simulation with satisfactory performance. Extracted watershed characteristics from a DEM are essential for hydrologic analysis and provide support for water resources management in different areas. The study is conducted solely by extracting hydrologic information using arc hydro tool and DEM, without considering other factors including rainfall, temperature, evaporation, etc. Different factors might influence the accuracy of the watershed modeling using Arc Hydro. Therefore future research with the consideration of more features and other parameters in setting up the Arc hydro is desired and improve the precision of the characteristics of a watershed.

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