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1 **Tiling watersheds with hexagons and geospatial**
2 **information for serious games**

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7 **Abstract.** Serious games have become key tools to study the water
8 management in the presence of stakeholders. Such role-playing sessions bring
9 people around game boards to facilitate discussions beyond traditional positions
10 and (sometimes) to trigger positive changes in both representation and behavior.
11 Usually drawn in a synthetic manner, the board (also called “world”) may also
12 be proposed as a realistic interpretation of actual environmental data. This
13 presentation proposes a software for tiling actual watersheds with hexagons.
14 Based on the Topotoolbox, the XGeoTiles GIS software is designed for the
15 watershed delineation and its hexagonal paving in a simplified but realistic
16 manner. Given elevation and land cover data rasters, tiles are drawn as
17 hexagonal flat homogeneous parcels. For each of the tiles, the height is set to
18 the minimum height while land cover is set to the dominant cover (cropland,
19 natural and urban) over the actual land parcel. The flows are restored.
20 XGeoTiles generates shapefiles that are compliant with QGIS.
21 Illustrative examples are the slightly undulating rural watershed of the
22 Moderbach stream (Grand Est region, France, 89 km²) and the rural land-sea
23 watershed flowing to the Bay of Morlaix (Brittany region, France, 312 km²) to
24 offer different gaming opportunities. The tile number is set to about 90 for the
25 Exp’Eau serious game on water quality in rural catchments. In a nutshell,
26 players choose crops (crops or breeding) and level of practice (intensive,
27 normal, bio), may implement eco-friendly measures (buffer strips) and
28 exchange with other players so as to limit water contamination or to improve
29 water quality.
30 Smaller the hexagons, more accurate are the landscape and stream
31 representations. Where gaming rules are not fully satisfied (same number of
32 tiles per player) some hand-coded adaptations may be carried out using either
33 Matlab or QGIS. Note that the conceptual hydrological modeling (gray-box
34 model) is little impacted since the watershed area is well approximated (other
35 parameters remaining constant).
36 In conclusion, in addition to the reliability of the representation, various gaming
37 sessions showed that such gaming boards help stakeholders in their handling of
38 Exp’Eau and their immersion into their player roles.

39 **Keywords:** Gamification, Geoinformatics, Watershed paving, Elevation model,
40 Land cover.
41

42 **1 Introduction**

43 Serious games on water governance bring people on a particular question together
44 such that they may overcome traditional positions and may trigger positive changes in
45 both representation and behavior. Boards and role-playing, possibly enforced by
46 computer simulations, have become key tools [1] to study water management in the
47 presence of stakeholders. Usually drawn in a synthetic manner, the board (also called
48 “world”) may also be proposed as a realistic interpretation of actual environmental
49 data such as Digital Elevation Models (DEM, [2]) and Land Cover data (LC, [3]).

50 After being studied for a long time, hexagonal tiling is receiving renewed attention
51 in the Geographical Information System (GIS) community [4]. The XGeoTile
52 framework is proposed for the representation of actual watersheds as 2D and 3D
53 boards that preserve the hydrological and geographical meanings. Based on
54 Topotoolbox [5], the method is designed for the hexagonal tiling of watersheds in a
55 simplified yet realistic manner, as illustrated in two examples (Moderbach catchment,
56 Grand-Est, and Morlaix Bay, Brittany, France). Resulting boards are parts of the
57 Exp'Eau game box, a serious game for exploring pathways to improve water quality
58 in agricultural catchments [6].

59 **2 Materials and Methods**

60 Present in nature-based solutions like honeycombs or crystals, hex tiles and hex
61 prisms have a number of useful properties. Given a tile, the availability of 6 adjacent
62 tiles and the equal distance between their centroids have retained the attention in a
63 large number of strategy games. In particular, hexagonal tiles offer more directions
64 for the moves of water and other resources from one tile to the others. Such a
65 tessellation may thus offer a nicer representation of the landscape.

66 Written in Matlab, TopoToolbox [5], an object-oriented hydrology toolbox,
67 provides functions to manipulate rasters (as GRIDObj objects). Provided with a DEM
68 (raster) and an outlet, this tool allows for the determination of the stream network and
69 the delineation of the drainage basin (DB). The DEM and LC rasters may be then
70 cropped with respect to DB, see Fig.1 for an example.

71 The XGeoTiles GIS software builds on Topotoolbox to implement a GIS treatment
72 designed for the hexagonal paving of the DEM and LC rasters, and the provision of
73 an adapted stream network. Tiles are drawn as hexagonal flat homogeneous parcels.
74 The watershed tiling is limited to the set of tiles that overlap or partly overlap the
75 drainage basin. A threshold, for instance an overlap larger than 0.5 is imposed. The
76 height of any tile is set to the minimum height while the land cover is set to the
77 dominant cover (cropland, natural, urban, waterbodies) within the actual hexagonal
78 land parcel.

79 Flows are reinstated in accordance with the elevation gradient. In typical watershed
80 scenarios, the stream network displays a tree-like structure, with each sub-basin
81 possessing a distinct outlet. However, this may not hold true when employing tiling
82 techniques. XGeoTiles positions the tile outlet face as the one comprising the lowest
83 elevation point among the DEM pixels within the tile. This coarse yet functional

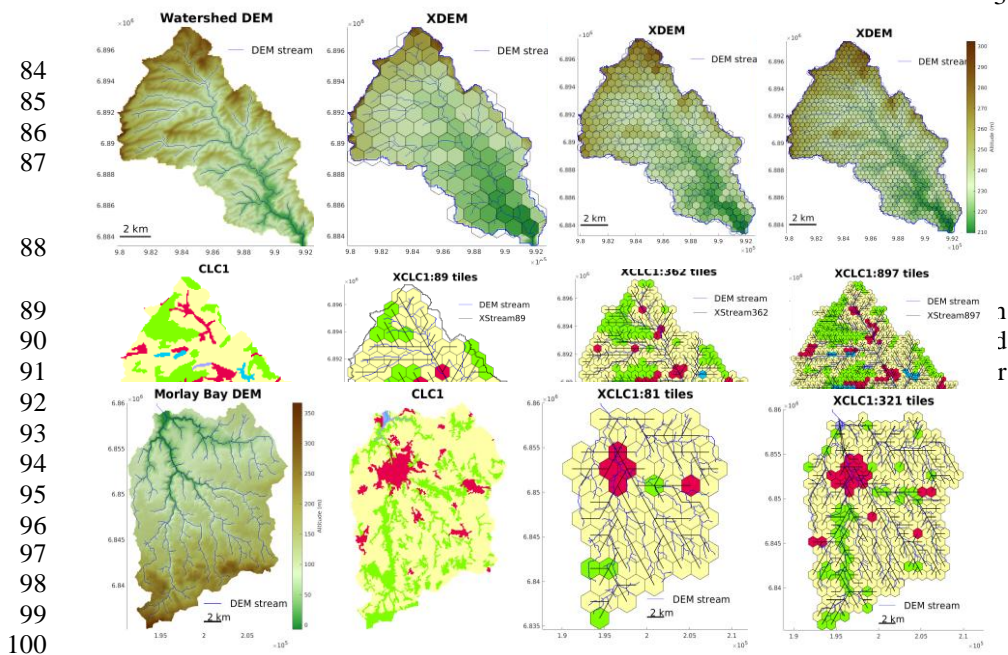
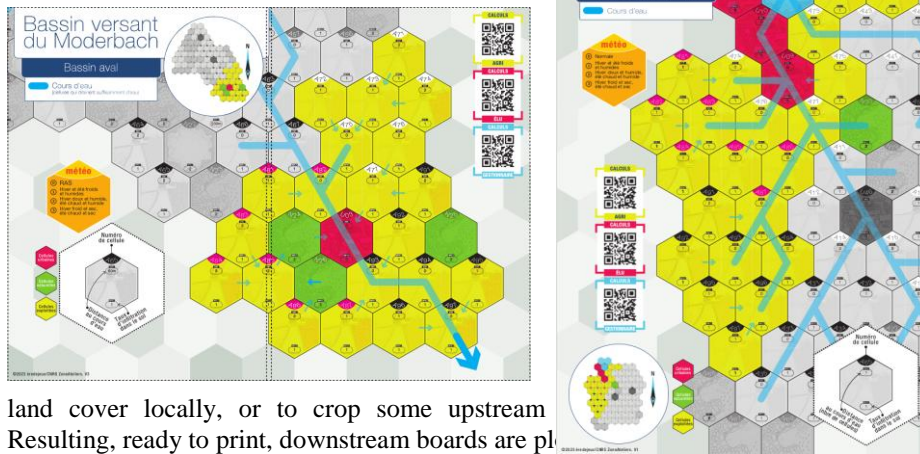


Fig. 2. Morlaix Bay: Tiling using the DEM and the Corine Land Cover data (level 1).

103 4 Discussion

104 The XGeoTile framework is proposed for the representation of actual watersheds as
105 2D and 3D boards that preserve the hydrological and geographical meanings.
106 Hexagonal tiles and prisms are favored as they offer more directions for the moves of
107 water and contamination. Key hydrological characteristics are maintained while using
108 conceptual hydrological models such as [7,8]. Indeed, these rely on a very few soil
109 and vegetation parameters to link the rainfall to the discharge at its outlet. Moreover,
110 in these gray box models, the area acts as a scaling factor applied to calculations
111 performed on a unit of field. The larger the number of tiles, the better the
112 approximations of the area and the hydrological modeling results. Similarly, the larger
113 the number of tiles, the better the land cover representation (vegetation and soil).

114 The serious game Exp'eau on water governance and pollution management was the
115 intended application. In this game, each catchment is divided into 3 boards (upstream,
116 1 central, 1 downstream basins for the Moderbach catchment; 2 upstream basins, 1
117 downstream basin for the Morlaix Bay), each comprising 21 farming tiles (7 tiles per
118 farmer), at least 1 urban tile and a variable number of natural cells. On the one hand,
119 the watershed partition into boards and the simplification of the stream network (for a
120 better readability) are performed with XGeotiles. On the other hand, the gaming
121 constraints require some change in the tiles' land cover (nature vs. farming) because
122 the use of actual data (see Fig. 2) cannot ensure the desired distribution of cells. To
123 that end, one may handle the vectorial data sets generated by XGeoTiles to change the



124 land cover locally, or to crop some upstream
 125 Resulting, ready to print, downstream boards are pl

127 **Fig. 3.** Exp'Eau "downstream" boards (Final design: Ere de Jeux).

128 The actual cell size has long been debated among the designers of the Exp'Eau game.
 129 This resulted in a compromise: on the one hand the cell does not have a valued area,
 130 on the other hand each player represents a more or less large set of farmers [7].

131 These boards were successfully tested in Exp'Eau gaming sessions involving
 132 Bachelor and Master students. Several Master programs have expressed their interest
 133 for the game to explore the educational potential of such a tool. Ultimately, this game
 134 should be played with stakeholders from the territory of a watershed [6].

135 5 Conclusions

136 The XGeoTile framework is proposed to turn DEM and catchments into 2D and 3D
 137 hexagonal boards while maintaining their hydrological and geographical significance.
 138 A hydrological analysis based on gray box models validates the accuracy of this
 139 representation. Likewise, land cover information is well captured when a suitable
 140 granularity of tiles is utilized.

141 Various gaming sessions showed that such boards help the stakeholders (mainly
 142 students and researchers for the moment) in their handling of Exp'Eau and their
 143 immersion into their player roles.

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