JAG • Volume 1 - Issue 3/4 - 1999

Use of geomorphological units to improve drainage network extraction from a DEM

Comparison between automated extraction and photointerpretation methods in the Carraixet catchment (Valencia, Spain)

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KEYWORDS: drainage network, Digital Elevation Model, geomorphology

ABSTRACT

Drainage networks are one of the main elements characterizing basins, and network topology and geometry form the basis of many hydrological and geomorphological models (*eg* Geomorphological Unitary Hydrograph). The identification and manual delineation of channel networks from maps or aerial photographs requires much time and effort. In the last two decades, algorithms and procedures for automated extraction of drainage networks from digital elevation data have been developed and implemented in many specialized software applications. Nevertheless, automatically delineated channel networks do not always show close agreement with manually delineated networks. This paper describes a comparative analysis between a drainage network automatically extracted from a gridded digital elevation model, and the drainage network delineated manually from stereographic pairs of aerial photographs. The analysis showed that the automatic extraction technique may be adequate for catchment headwaters, but is inappropriate in the middle and lower basins, especially for alluvial fans and calcareous platforms. The paper suggests improving the automatic extraction technique by adapting it to operate with different parameters for each of the geomorphological units within the catchment.

INTRODUCTION

Drainage networks are important not only to hydrologists but also to geologists, geomorphologists, agricultural engineers and other environmental professionals. They can be considered as the synthesis of many landscape properties, such as climate, topography, soil and lithology, geological structures and vegetation cover.

Traditionally, manual methods have been used to delineate drainage networks from field data, topographical maps, aerial photographs, satellite images, and combinations of these. Delineation of networks is very scale dependent and, when detailed information is required, a long and laborious task.

Recently, increasing use of Geographical Information Systems (GISs) by the hydrological community [Vieux, 1991; Drayton *et al*, 1992; Wilde & Harris, 1992; Kovar & Nachtnebel, 1993] has led to increasing demand for digital data. To obtain digital data for superposition on other geocoded data, first paper maps that have been produced by traditional, manual methods [Jarvis, 1977] have to be digitized. In addition to being an extremely time-consuming and tedious process, the transformation of manually-extracted drainage networks into digital form also introduces errors when the digitized network is integrated with, or superimposed upon, other topographic and land use coverage.

The real advance is to be found in automation of the extraction of drainage networks from Digital Elevation Models (DEMs) through the use of computer algorithms. Many procedures using different programming languages have been developed for this. Tribe [1992] in his review found three main approaches for automated recognition of valley and drainage cells: (a) the recognition of individual DEM cells as valley cells, where a cell is classified as a valley if certain cells surrounding it are higher than that cell [Peuker & Douglas, 1975; Torwaki & Fukumura, 1978; Douglas, 1986]; (b) the assignment of drainage directions to each DEM cell and the use of this information to derive a drainage network [O'Callaghan & Mark, 1984]; and (c) more complex methods based on the combination of these two approaches. The main problems with these approaches are the positioning of the ends of drainage networks and the assignment of drainage directions to individual cells, in particular across flat areas and closed depressions or "pits" [Tribe, 1992].

Considerable advances have been made over the last few years in solving these problems [Jenson & Domingue, 1988; Donker, 1992; Helmlinger *et al*, 1993; Dymond & Harmsworth, 1994], and algorithms for automated network extraction have been implemented in some commercial systems. Donker [1992] describes the general procedure which most of the algorithms follow. It is based on four essential data level matrices: an elevation matrix, a flow directions matrix, a ranked elevation matrix, and a flow accumulation matrix.

The elevation matrix provides the basis for the calculations. It consists of a regular grid of elevations that represent a sample of the real topography, *ie* a DEM or a Digital Terrain Model (DTM). The flow direction for a cell matrix is the direction water flows out of the cell, from the eight possible directions, following the maximum downward slope. In the ranked elevation matrix the cells of the DEM are ranked from highest to lowest elevation. Finally, the flow accumulation matrix contains the contributing drainage area of each cell. All cells with a value higher than a certain threshold form a connected drainage network, provided that the DEM has no pits or depressions without outlet.

Because automated network extraction is becoming widely used, it seems necessary to improve the methods used, as automatically delineated networks do not always show close agreement with manually delineated ones. This paper makes a comparative analysis between a drainage network automatically extracted from a gridded DEM and the drainage network delineated manually from aerial photographs. A small basin, the Carraixet catchment on the Spanish Mediterranean coast, was selected as the study area.

STUDY AREA

The basin used in this study is the drainage area of the Carraixet ephemeral stream, a small catchment of 311 km^2 which extends from 39° 29′ N to 39° 50′ N and from 0° 16′ W to 0° 35′ W, located in the eastern part of the Cordillera Iberica (Spain). The stream flows into the Mediterranean Sea to the north of Valencia, Spain's third largest city, so the catchment includes areas of intensive land use. The catchment has an elongated and asymmetrical shape (elongation rate 0.23), marked relief (over 22 percent of the area has slopes steeper than 30 percent), and is strongly influenced by underlying geological structures.

The geomorphology of the basin is very varied [Camarasa, 1995]. Four main sectors can be differentiated: its headwaters, an intermediate area of alluvial fans, a calcareous platform, and an alluvial plain (Figure 1).

- The headwaters are in the mountainous area formed by highly resistant Mesozoic materials (limestone, dolomites and sandstone). It has a typical germanic relief, *ie* highly faulted and very steep.
- The intermediate sector is formed by a series of deep alluvial fans and piedmonts formed during several Quaternary phases, overlaying a faulted and sunken Pliocene graben. Several paleochannels can be identified on the surface of the alluvial fan system, revealing the existence of paleonetworks.
- A calcareous sub-tabular platform borders the south of the middle basin. In this sector the drainage system is semi-endorreic, mainly composed of valleys and plain-floor channels that form a fluviokarst network. This drainage system is, therefore, disconnected from the main, general network.
- Finally, the convex alluvial plain constitutes the lower basin. Here the main channel is highly regulated by human activity, and has an overflow basin on either side. The plain is crossed by numerous irrigation channels, which shows the high degree of human activity in the area.

The Carraixet network has a high degree of asymmetry due to underlying geological structures. It is a seventh-order network (Horton-Strahler classification) with a very hierarchical dendritic sector in the headwaters, due to the steep slopes. In the middle and lower sectors of the basin, the network is dominated by the arrangement of the area's faults and the current positions of the channels across the alluvial fans, giving these sectors sub-dendritic characteristics. In the alluvial plain the channels are rectilinear due to a high degree of human intervention.

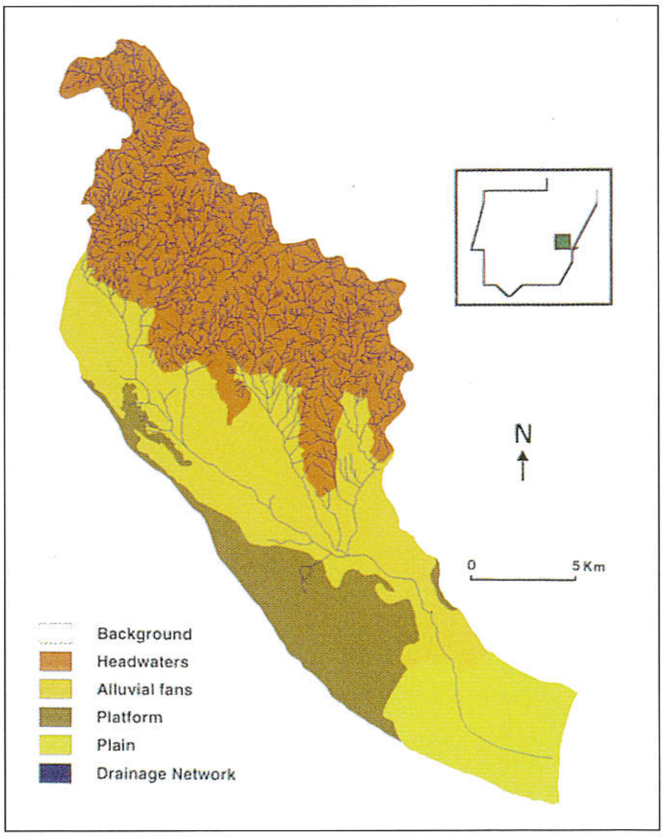

FIGURE 1 The Carraixet catchment divided into its four main geomorphological sectors. The current drainage network as obtained by photointerpretation techniques and fieldwork is shown.

METHOD

The method employed to evaluate the degree of adjustment between the drainage network extracted automatically from a DTM and the network delineated manually comprises three steps: manual delineation, automated delineation, and comparison of the two results.

MANUAL DELINEATION OF DRAINAGE NETWORK

Traditional, manual methods of delineating drainage networks require questions related to the scale of the work, sources of information, and techniques available to be taken into consideration before selecting the most appropriate method. Difficulties can appear when delineating first-order channels, as some criteria must be established to discriminate between small gullies and real channels [Gardiner, 1975; Zavoianu, 1985]. While for small scales the method of "blue lines" (printed stream networks on topographic maps) can be appropriate, for detailed scales it is convenient to complete the network by adding small valleys, whose presence is indicated by crenulations in the contour lines [Mark, 1983]. Errors arise whatever method is used to manually delineate drainage networks because the exact representation of the network is never possible. However, as observed by Zavoianu [1985], photointerpretation of stereoscopic pairs combined with fieldwork leads to more accurate delineation.

The network of the Carraixet catchment was drawn from photointerpretation of 1:33,000 scale aerial photographs combined with fieldwork. Subsequently, the network was transposed onto a topographical map at 1:25,000 scale in order to help compute watershed parameters. The criterion used to define first-order channels was that they have a channel morphology and a length of over 100 m. This length was proposed by Perez Cueva [1988] after he had studied the very high density of channels in the upper reaches of the basin as the most suitable for this catchment for identifying small tributaries. The use of a short length for first-order channel detection guarantees detailed and reliable network delineation, as shown in Figure 1.

Some other controversial aspects for the photointerpreter have to do with the possible presence of paleochannels, which are often disconnected from the present network but can become functional during flooding. This problem is especially important in poorly organized undeveloped networks, in semi-arid environments, and in basins with a strong structural influence or with significant human intervention.

The Carraixet catchment is a very dynamic basin, which has experienced several evolutionary phases during the Quaternary age and, consequently, shows evidence of older networks. This geomorphological inheritance is clearly seen in the alluvial fans and piedmonts, where there are divergent paleochannels that in the past drained Pleistocene alluvial fans.

The Carraixet network as shown in Figure 1, and as interpreted manually by the authors, represents the real, present-day drainage network, as care was taken to avoid any Pleistocene paleochannels. The channels are becoming entrenched in their own sediments and the network is well organised.

AUTOMATED EXTRACTION OF DRAINAGE NETWORK

The automated extraction of the Carraixet network was carried out from a DEM of 1:50,000 scale, in raster format, with a 25 m x 25 m grid cell size, which was provided by Spanish Geographical Military Service. The DEM data are registered in the UTM coordinate system and are a standard product that is cheap and commercially available for the whole of Spain. The whole Carraixet drainage area was covered by a matrix of 1680 rows by 1160 columns.

PCI Inc. software, Version 6.0 [1996] was used to extract drainage channels. The specific programs used were DWCON and DRAIN, both of which included in the Module "Basin Hydrology". DWCON and DRAIN procedures are based on the algorithms described by Jenson & Domingue [1988].

The DWCON program is run prior to any other program as a "conditioning phase", which prepares the DEM data for further drainage analysis. This involves a cleanup process and the generation of four new images [PCI, 1996]:

- *The Depressionless DEM*

Depressions present a significant problem in flow prediction models for two particular reasons. First, depressions in DEMs are often data errors introduced during the DEM interpolation process. Second, depressions serve to confuse flow direction models, because they must be filled before flow can continue. In most models flow ceases once a minimum elevation is encountered. Depressions are localized occurrences of minimum elevations and cause most flow models to stop or generate erroneous results. To avoid these problems all depressions in the DEM are located and filled (each pixel within a depression is assigned the elevation of its edge or spill point).

- *The Flow Direction Matrix*

Water at any given pixel location will flow to one of its eight adjacent neighbouring pixels. The Flow Matrix indicates this neighbouring direction of flow for each pixel in the depressionless DEM. The direction of flow is iteratively calculated so that the flow path follows a continuous downhill path.

- *The Flow Accumulation Matrix*

In this image, each pixel that represents the number of pixels whose water flows to its location is assigned a grey value. For example, pixels having a flow accumulation value of zero correspond to the drainage divides in the image.

- *The Change in Flow Matrix*

In this image, each pixel that represents the amount of increase in flow accumulation is assigned a grey value.

After the conditioning phase, the program DRAIN was used to determine the drainage networks (river or stream courses) from the Flow Accumulation Matrix. A threshold indicating the minimum number of cells required to form a channel (flow accumulation value) must be defined by the user. This is a key parameter in automated network extraction and can be considered as the minimum support area required to drain to a point for a channel to form. The choice of the threshold area obviously influences the final result and generally a constant catchment-wide value is assumed. Helmlinger *et al* [1993] emphasize the need for an appropriate choice of threshold as the morphometric properties of the network vary considerably depending on its value [Gandolfi & Bischetti, 1997].

In the automated extraction of the Carraixet network, the mean area of first-order stream (Horton-Strahler classification) - 0.08 km^2, equivalent to 128 cells - was taken as the minimum support area to form a channel. This value was known from the analysis of the network (Figure 1), which had previously been extracted by photointerpretation. Normally a value is chosen based on arbitrary judgement or visual comparison of the generated network with the blue lines.

COMPARISON BETWEEN MANUALLY AND AUTOMATICALLY EXTRACTED NETWORKS

Obviously both networks contain errors. For our comparison we took the manually extracted network to be "ground truth". This is partly because the more detailed scale of the aerial photographs (1:33,000) and the fieldwork guarantees a good reference map with which to compare the network obtained from the DEM. Also, it provides an independent reference against which to compare the different networks extracted by automated procedures using different input parameters.

The manually delineated network was digitized in vector format, rastered and converted to the same grid as the DEM. The comparison was performed using IDRISI software (Version 4.1). Two main features were considered in the comparative analysis: the spatial pattern of the drainage lines, which was evaluated by both visual analysis and by calculating the degree of coincidence between the two networks; and, as a relevant morphometric index, the drainage density computed for each network. The different sources of the files (aerial photographs translated to a digital map for the manually extracted network, and a DEM for the automated one) produce relative geometric errors which makes it difficult to quantify the degree of coincidence of the lines by simple superposition. In order to minimize these errors, the drainage lines were made broader by one pixel on either side of the channel by applying a low-pass filter or smoothing through a 3 x 3 kernel [Gonzalez & Wintz, 1977]. The result of this process can be seen in Figure 2. The ratio of coincidence between the networks was calculated as the percentage of the total automatic network which agrees with the manual network. Although this method tends to underestimate the degree of coincidence (see Figure 2), especially where geometric distortions are greater than one or two pixels, it was used because it is very easy to apply.

The drainage density was calculated for both networks as the total length of the channels (km) divided by the total basin area (km^2). Non-filtered images were used for this process.

RESULTS OF COMPARISON AND DISCUSSION

COMPARISON OF THE TWO NETWORKS

The comparison of the spatial patterns of the two drainage networks (Figure 2) reveals poor agreement. Only 29 percent of the total automatic network coincides with the manual pattern. However, good correspondence can be observed in some parts of the basin. When the analysis was repeated after dividing the basin into its four main geomorphological sectors (described in *Study Area*), better agreement (Figure 3) was found in the headwaters sector (62.2 percent) than in the rest of the area (alluvial fans, 14.5 percent; platform, 1.5 percent; and plain. 2.3 percent) (Figure 4).

With respect to the drainage density, a value of 1.99 km/km^2 was obtained for the whole manual network and 2.22 km/km^2 for the automatic one. Although these general figures are fairly similar they are not a good indicator of the spatial correspondence of the networks. Table 1 shows the values of drainage density obtained for each geomorphological sector in the manual network and those obtained for the automatic network. Quite different values have been obtained in every sector.

GEOMORPHOLOGICAL PROCESSES AND NETWORK DEVELOPMENT

The poor correspondence between the two networks could be due to the inability of the automated network-extraction method to consider the dynamic aspects of the drainage system. These methods use a single flow accumulation value to characterize the whole of the basin. The drainage basin is considered as just a geometric surface divided into drainage and channel cells.

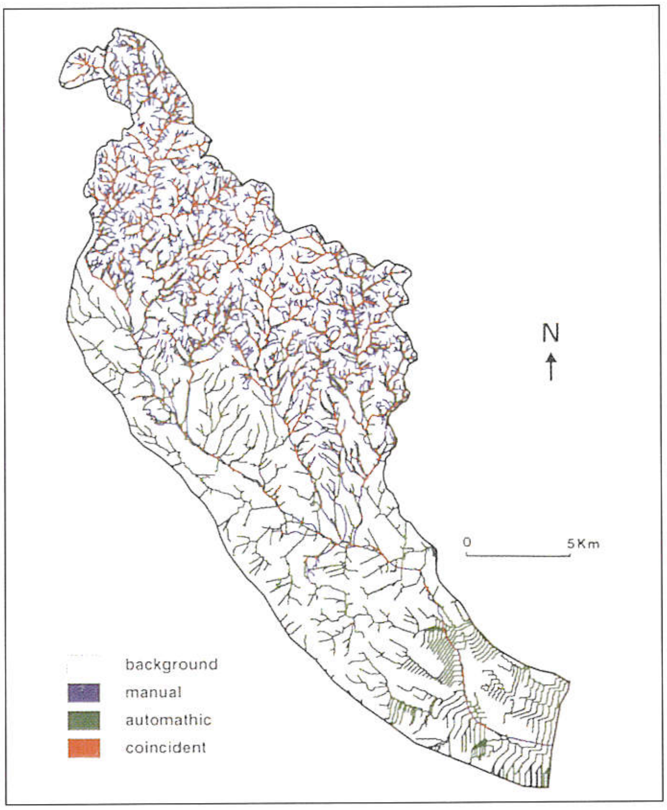

FIGURE 2 Comparison between the drainage network manually delineated by photointerpretation and the automatic network obtained from a DEM

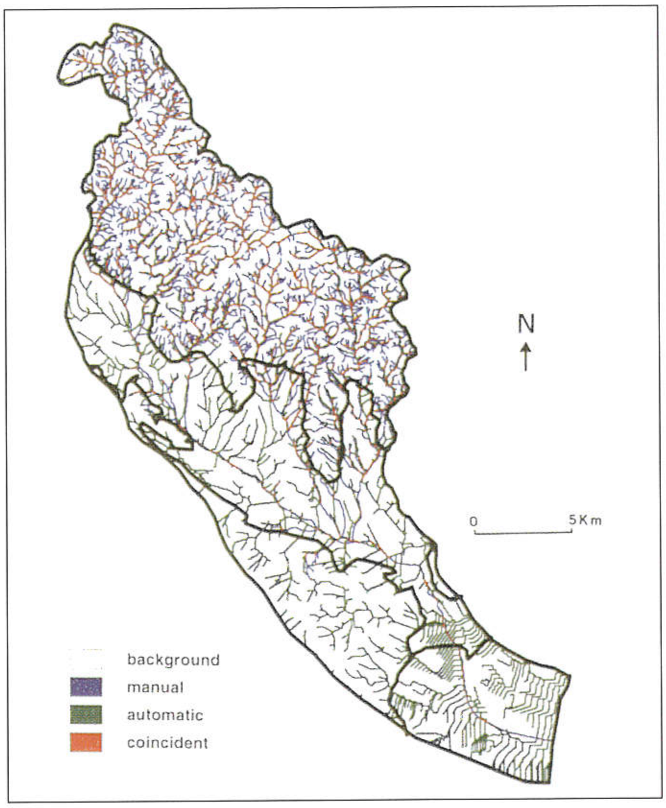

FIGURE 3 Comparison between the drainage network manually delineated by photointerpretation and the automatic network obtained from a DEM in the four geomorphological sectors

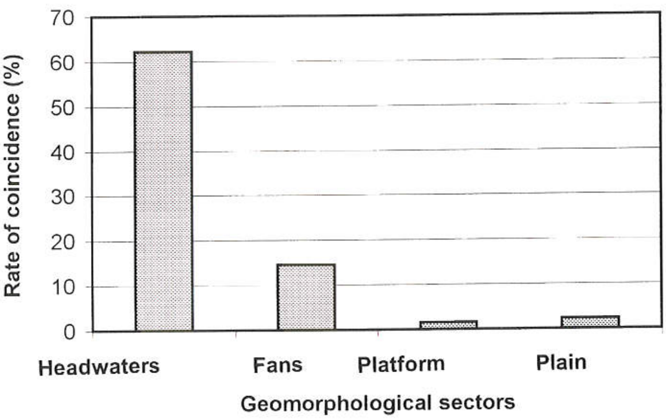

FIGURE 4 Rate of coincidence (%) between manually and automatically delineated networks in the four geomorphological sectors

TABLE 1 Drainage density (km/km2) calculated in the four geomorphological sectors for the manually and automatically delineated networks

Network type	*Headwaters*	*Alluvial fans*	*Platform*	*Plain*
Manual	3.82	0.94	0.11	0.17
Automatic	1.87	2.39	1.70	3.22

However a drainage basin cannot be considered as a mere topographical surface. It is the result of a complex geomorphological evolution and is better considered as an open process-response system with energy and matter inputs and water and sediment outputs [Chorley & Kennedy, 1971; Schumm, 1977; Morisawa, 1985]. Basin forms adapt to the dominant processes in a dynamic way (erosion/accumulation) and, consequently, the morphology of the basin responds to the energy budget.

These dominant processes vary temporally and spatially. In the past (Pleistocene) the Carraixet catchment developed forms different to the present ones; they were adapted to different conditions. These forms can be found today as inherited relics. Furthermore, each sector in the basin has different dominant processes and, consequently, shows different associated forms.

The network, as a prime component of fluvial morphology, is conditioned by this dynamic behaviour. In general, erosive processes dominate in upstream areas, transport processes dominate in the middle sector, and accumulation dominates in the lower basin. Consequently, networks tend to have numerous channels in the headwaters (with a small number of flow accumulation cells per channel unit), a few channels of a superior order in the middle basin (with a higher number of flow accumulation cells), and a unique well-developed channel in the plain (where the number of flow accumulation cells will tend to be the total area of the catchment).

In the Carraixet catchment, the comparison between the automated and manually extracted networks showed better agreement in the headwaters because the threshold value used for network extraction (mean first-order channel area) corresponds to the channel order that predominates in the area. For the rest of the basin this threshold is too small. The automated method depicts a high density of channels, which does not agree with the main geomorphological processes dominating these areas. The highest errors were found in the platform area (98.5 percent) and in the plain (97.7 percent). Lower error (85.5 percent), although still considerable, was found in the alluvial fans and piedmont sector.

The calcareous platform has an endorreic hydrological behaviour with karstic absorption depressions and small valleys, which only carry water during severe flooding. These (poorly developed) small valleys are disconnected from the main network. However, these depressions are present in the DEM and the automated network-extraction method generates drainage lines that erroneously connect them to the main network (Figure 3).

In the plain, the main channel forms a convex surface with natural dykes surrounding the river banks and with flood basins on either side of the channel. This morphology and the several irrigation channels in the area confuses the automated extraction method, which depicts small valleys, irrigation channels and other false lines as channels connected to the main network (Figure 3).

In the alluvial fans and piedmont sector, the poor agreement between the networks can be seen in the different channel routes and in the channel densities. An explanation for this seems to be related to the grid cell size and to the presence in the area of paleochannels and relic forms. On the one hand, a 25 m x 25 m cell size is too big to allow the model to detect the narrow, entrenched channels in the fan surface. In this alluvial fan morphology, slopes diverge from the central part of the fan to the lateral depressions, and the channel is entrenched in the central axis. As the cell size did not permit detection of this channel, the general slopes erroneously generated drainage lines flowing towards the lateral depressions. On the other hand, remains of a Pleistocene network are still recognisable in this sector and the depression morphology of these paleochannels helps to create errors in the automated network extraction as an older network is added to the current one.

AUTOMATED EXTRACTION WITH A VARIABLE THRESHOLD AREA

Taking into account the specific characteristics of the catchment, new automated network extractions were performed using different threshold areas for each geomorphological sector. The optimum threshold used in each sector was selected according to the predominant channel order in each zone. An average area value was estimated and converted into the corresponding number of cells (flow accumulation value) (Table 2). The headwaters' sector shows steep slopes and high energy with a predominance of first-order channels (average area of 0.08 km^2 = 128 cells). In the alluvial fans and piedmont sector, fifth-order channels predominate (average area of 21.33 km^2 = 34,128 cells). For the calcareous platform, which shows a fluviokarstic drainage disconnected to the main network, and the plain area, the maximum area (260 km^2 = 416,000 cells) was assigned, corresponding to the seventh order.

Three new automatic networks were obtained and compared with the manually delineated network, which was also reclassified into three new networks (from first-order channels, from fifth-order channels and from seventh-order channels).

Quantitative comparison between the networks was performed for each sector by the method described previously. First-order networks were used in the headwaters, fifth-order networks were used in the alluvial fans and piedmont sector, and seventh-order networks were used for the platform and the plain.

Figure 5 shows the coincidence ratio between manual and automatic networks for each sector obtained, both for the new networks as well as the previous data shown in Figure 4. Although coincidence between manual and automatic networks was still poor, better agreement could be observed when specific thresholds were used for each sector (variable-order network) than when a single threshold is used for the entire basin. An improvement of 10 percent is achieved in the alluvial fan sector and 8 percent in the plain area.

The results of the analysis of drainage density are summarised in Table 3, which shows better agreement between the values of drainage density obtained in the manual and those obtained for the automatic network.

TABLE 2 Optimum threshold area applied in each geomorphological sector

Geomorphological sectors	*Dominant processes*	*Area thresholds*	*Cells (km^2)*	*Reference order (Horton-Strahler)*
Headwaters	Erosion	0.08	128	1
Alluvial Fans	Erosion/ Accumulation	21.33	34,128	5
Calcareous Platform	Karstic erosion	260	416,000	7
Plain	Accumulation	260	416,000	7

From these results, we set out to improve automated network extraction of the Carraixet basin by selecting a different threshold area (flow accumulation cells) in each geomorphological sector of the basin. This value is directly related to the main stream order of each sector and indirectly to the dominant geomorphological processes. Figure 6 shows the network extracted automatically by this method. Although some of the errors in the middle and lower basins - already commented on in the text - are still present, the resulting network agrees much better with that manually extracted than when the extraction uses a single threshold for the whole basin.

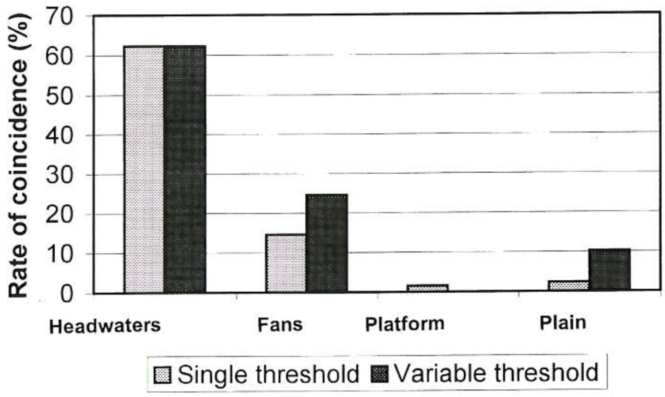

FIGURE 5. Rate of coincidence (%) between manual and automatic network in the four geomoprhological sectors. Comparison of the results obtained when a single and a variable threshold area are used

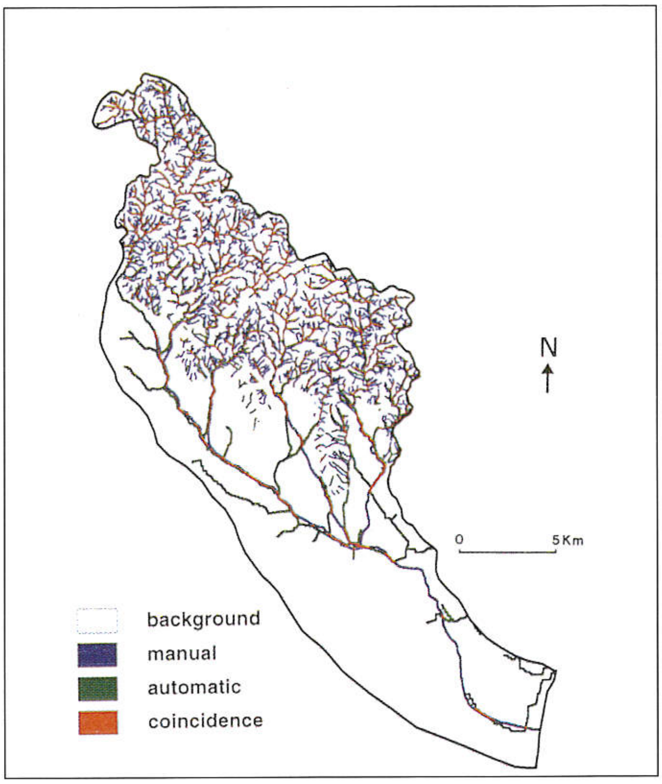

FIGURE 6. Comparison between the drainage network manually delineated by photointerpretation and the network extracted automatically by the method proposed

CONCLUSIONS

From the comparison of manual and automated network extraction in the Carraixet catchment, we are able to draw some conclusions that could be extrapolated to similar areas. Despite the limitations of the method used for comparison, in general poor agreement has been found between the automatically extracted network and the manually extracted one. However, different degrees of agreement appear in different parts of the basin. The automated extraction technique seems to be appropriate for catchment headwaters but not for the middle and lower basins, especially in the sector of alluvial fans.

The results of the automated extraction method depend highly on the definition of an appropriate threshold (minimum number of cells required to form a channel unit). This number is very dependent on the geomorphological features of the basin, which very often vary considerably from one part of the catchment to another. A prior analysis of the geomorphology of the basin is advised to determine the most suitable thresholds.

We suggest that automated extraction can be improved by dividing the basin into geomorphological sectors and using a different threshold in each sector. The subdivision of the drainage area allows the definition of a threshold area that takes into account the predominant channel order and, consequently, the dominant processes-forms acting in each zone. In addition, the geomorphology of the area is very important for a proper explanation of anomalous patterns in the automatic networks. Paleochannels, relic forms, irrigation channels, etc., all have a topographical expression, but they do not always belong to the current drainage network.

The reliability of drainage networks that have been extracted automatically from DEMs seems to be dependent on the geomorphological characteristics of the terrain. Although further studies in other drainage basins would be necessary to confirm these results, the study in the Carraixet suggests that in catchment headwaters - high areas with steep slopes - automated extraction can

TABLE 3. Drainage density (km/km^2) obtained in the four geomorphological sectors using variable threshold areas for automated network extraction

Network type	*Headwaters (128 cells)*	*Alluvial fans (34,128 cells)*	*Platform (416,000 cells)*	*Plain (416,000 cells)*
Manual	3.82	0.45	0.0	0.18
Automatic	1.87	0.8	0.0	0.29

be used reliably. However, in poorly organised basins with shallow slopes the definition of an appropriate threshold area - related to the channel order - to be used in the automatic extraction algorithm is very important. In mixed catchments similar to the Carraixet, with piedmonts and alluvial fans, automated extraction should be used with caution, as the network obtained does not always adjust to the present day channel pattern.

ACKNOWLEDGMENTS

This study is part of the project 'Hydrogeomorphology of the Valencian Rivers' funded by the Spanish National CICyT, AMB 95-0817 (1995-1998) and the project 'GIS and Flood Modelling' funded by the Valencian Regional Goverment, GV-D-RN-12-127-96. The authors wish to thank B.J. Denore who kindly reviewed the English text.

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RESUME

Les réseaux de drainage sont l'un des éléments principaux caractérisant les bassins ; la topologie des réseaux et la géométrie forment la base de beaucoup de modèles hydrologiques et géomorphologiques (ex. Hydrographe unitaire géomorphologique). L'identification et la délineation manuelle des réseaux de canaux à partir de cartes ou de photographies aériennes requièrent beaucoup de temps et d'effort. Ces deux dernières décennies, des algorithmes et procédures pour une extraction automatisée ont été développés et mis en œuvre dans beaucoup d'applications de logiciels spécialisés. Cependant, des réseaux de canaux automatiquement délinéés ne montrent pas toujours une concordance parfaite avec des réseaux délinéés manuellement. Cet article décrit une analyse comparative entre un réseau de drainage extrait automatiquement à partir d'un modèle numérique de terrain et le réseau de drainage délinéé manuellement à partir de stéréopaires de photographies aériennes. L'analyse a montré que la technique d'extraction automatique peut convenir pour un captage des eaux des bassins supérieurs, mais qu'elle est inapropriée pour des bassins moyens et inférieurs, spécialement pour des cônes d'alluvions et des plateaux calcaires. Cet article suggère d'améliorer la technique d'extraction automatique en l'adaptant pour opérer avec différents paramètres pour chacune des unités géomorphologiques à l'intérieur du captage.

RESUMEN

Las redes de drenaje son uno de los principales elementos característicos de las cuencas, y la topología y geometría de estas redes constituyen la base de muchos modelos hidrológicos y geomorfológicos (por ejemplo, Hidrografía unitaria geomorfológica). La identificación y delineación manual de las redes de canales a partir de mapas o de fotografías aéreas requiere mucho tiempo y esfuerzo. En las dos últimas décadas, se han desarrollado algoritmos y procedimientos para obtener de forma automática estas redes de drenaje a partir de los datos de altitud digitales que se han puesto en práctica en muchas aplicaciones de programas especializados. Sin embargo, las redes de canales delineadas automáticamente no siempre concuerdan con las redes delineadas manualmente. En este artículo se presenta un análisis comparativo entre una red de drenaje obtenida automáticamente a partir de un modelo de altitud digital de rejilla y la red de drenaje delineada manualmente a partir de pares estereográficos de fotografías aéreas. El análisis demostró que la técnica automática puede ser apropiada para las cabeceras de las cuencas, pero no es adecuada en las cuencas media y baja, especialmente en deltas aluviales y plataformas calcáreas. El trabajo sugiere la mejora de la técnica de obtención automática adaptándola al funcionamiento con distintos parámetros en cada una de las unidades geomorfológicas dentro de la cuenca.