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Spatial data integrated into numerical model for analysis meteorological and local climate in mountains of Cuba

Datos espaciales integrados a modelo numérico para análisis meteorológico y del clima local en montañas de Cuba

Dados espaciais integrados a um modelo numérico para análise meteorológica e climática local nas montanhas de Cuba

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ABSTRACT

Local-scale weather and climate modeling in mountains has been relevant for the study of agroforestry ecosystems and their future evolution. The study aimed to integrate a set of high-resolution spatial data to the WRF numerical meteorological prediction and research model, suitable for meteorological and local climate analysis in the mountains of Cuba. In the study, priority spatial data were defined as those referring to the relief, the land mask as the ocean-soil interface, the type of cover and type of soil. The national or global high-resolution spatial databases of the best quality and most appropriate to the characteristics of the model were selected. The databases integrated into the WRF had spatial resolution between approximately 0.95 and 0.03 km in Ecuador. The increase and updating of spatial data strengthened the model's capacity for the analysis of the geographic factors that shape the local climate, promoting better performance in the mountains. The research results could contribute to meteorological and climate monitoring and forecasting at a local scale for the mountains of Cuba. Likewise, studies and risk management associated with forest fires, severe hydrometeorological events, climate variability, climate change, and other dangers related to the climate system that have affected Cuban agroforestry ecosystems would benefit.

Keyword: numerical meteorological models, topoclimates, agroforestry ecosystems.

RESUMEN

La modelación del tiempo y el clima a escala local en las montañas han sido relevantes para el estudio de los ecosistemas agroforestales y su evolución futura. El trabajo tuvo como objetivo integrar un conjunto de datos espaciales de alta resolución al modelo numérico de predicción e investigación meteorológica WRF, adecuado para el análisis meteorológico y del clima local en las montañas de Cuba. En el trabajo, se definió como datos espaciales prioritarios los referidos al relieve, la máscara de tierra como interface océano-suelo, el tipo de cobertura y tipo de suelo. Se seleccionaron las bases de datos espaciales de alta resolución nacionales o globales de mejor calidad y más adecuadas a las características del modelo. Las bases de datos integradas al WRF tuvieron resolución espacial entre 0,95 y 0,03 km aproximadamente en el Ecuador. El incremento y actualización de los datos espaciales robustecieron la capacidad del modelo para el análisis de los factores geográficos formadores del clima local, propiciando mejor desempeño en las montañas**.** L*os* resultados de la investigación pudieran contribuir a la vigilancia y pronóstico meteorológico y climático a escala local para las montañas de Cuba. De igual manera, beneficiarían los estudios y gestión de riesgos asociados a incendios forestales, eventos hidrometeorológicos severos, la variabilidad climática, el cambio climático, y otros peligros relacionados con el sistema climático que han afectado los ecosistemas agroforestales cubanos.

Palabra clave: modelos numéricos meteorológicos, topoclimas, ecosistemas agroforestales.

RESUMO

A modelagem do tempo e do clima em escala local nas montanhas tem sido relevante para o estudo dos ecossistemas agroflorestais e sua evolução futura. O objetivo deste trabalho foi integrar um conjunto de dados espaciais de alta resolução ao modelo numérico de pesquisa e previsão do tempo WRF, adequado para a análise do tempo e do clima local nas montanhas de Cuba. No trabalho, os dados espaciais prioritários foram definidos como aqueles referentes ao relevo, à máscara de terra como uma interface oceano-solo, ao tipo de cobertura e ao tipo de solo. Foram selecionados os bancos de dados espaciais nacionais ou globais de alta resolução da mais alta qualidade e mais adequados às características do modelo. Os bancos de dados integrados ao WRF tinham resolução espacial entre 0,95 e 0,03 km aproximadamente no equador. Os dados espaciais ampliados e atualizados fortaleceram a capacidade do modelo de analisar os fatores geográficos que moldam o clima local, levando a um melhor desempenho nas montanhas. Os resultados da pesquisa podem contribuir para o monitoramento e a previsão do tempo e do clima em escala local nas montanhas de Cuba. Eles também beneficiariam estudos e gerenciamento de riscos associados a incêndios florestais, eventos hidrometeorológicos graves, variabilidade climática, mudanças climáticas e outros perigos relacionados ao sistema climático que afetaram os ecossistemas agroflorestais cubanos.

Palavra-chave: modelos meteorológicos numéricos, topoclimas, ecossistemas agroflorestais.

INTRODUCTION

The United Nations Declaration recognizes the conservation, restoration and sustainable use of mountain ecosystems and the services they provide, essential in achieving the goals of sustainable development. In Cuba, the implementation strategy of the National Economic and Social Development Plan for 2030 is carried out with the vision of confronting climate change. Correspondingly, the State Plan for Confronting Climate Change, "*Task Life*", *is implemented,* which specifies the need for analysis at a local scale. Agroforestry ecosystem services in Cuba are strongly linked to meteorological and climatic behavior at the local scale in the mountains, topoclimates (Molina-Pelegrín *et al.,* 2021; Zamora Fernández, Azanza Ricardo and Bezanilla Morlot 2022). These services are susceptible to forest fires, severe hydrometeorological events, climate variability and change, among other dangers associated with the behavior of weather and climate (Zamora Fernández and Azanza Ricardo 2020; Hardy Casado *et al.,* 2021; Pospehov *et al.,* 2023). This link also implies impacts on the macroeconomic balances and the livelihoods of the mountain people.

In recent years, there have been advances in methodologies and services for meteorological and climate monitoring in the Greater Antilles (Delgado-Téllez and Peña-de la Cruz 2019; Centella-Artola *et al.,* 2023; Peña-de la Cruz *et al.,* 2023; Torres and Lorenzo 2023). Likewise, these advances are seen within the projections of the future climate at a spatial scale favorable to the evaluation of the impacts and adaptation strategies to climate change (Centella-Artola *et al.,* 2020; Vichot-Llano *et al.,* 2021). However, meteorological and climate monitoring and forecasting, analogous to the future projection of topoclimates, are still insufficient for the management of agroforestry ecosystem services in Cuba. The generality of the limitations of weather and climate monitoring and forecasting systems for mountains at a local scale are related to the poor performance of methodologies and tools in representing the physical and dynamic processes involved.

The numerical meteorological model for prediction and weather research, WRF (NCAR 2018) is one of the most used tools in weather and climate studies at regional and local scales (Afrizal and Surussavadee 2018; Wang *et al*., 2020). One of the reasons is attributed to the fact that the software and the frontier data for its use are available globally to the scientific community. Other reasons for its multiple applications are the flexibility of its architecture and its precision. The official WRF distribution ships with a preprocessing system (WPS for its acronym in English) and a set of geographical variables such as relief, location of land masses, hydrology, types and uses of land, as static boundary conditions. These global scale variables have spatial resolution of 10 minutes, 5 minutes and 30 arc-seconds, approximately 18.5 km, 9.25 km and 0.95 km respectively at the equator. This spatial resolution is timely for its fundamental purpose of mesoscale analysis. However, when WRF is used on larger scales, for example, applications associated with the analysis of topoclimates for agroforestry ecosystem services in mountains, the boundary conditions supplied with the software generally cannot resolve local phenomena. In these cases, the inclusion of data adjusted to the defined modeling scale is required.

This research aims to integrate a set of high-resolution spatial data available, such as WRF frontier databases, suitable for meteorological and local climate analysis in the mountains of Cuba.

MATERIALS AND METHODS

The research was carried out for the entire Cuban archipelago, located at 74º 08', 84º 58' West longitude and 23º 17', 19º 50' North latitude, a total area of 109,886 km² (Figure 1).

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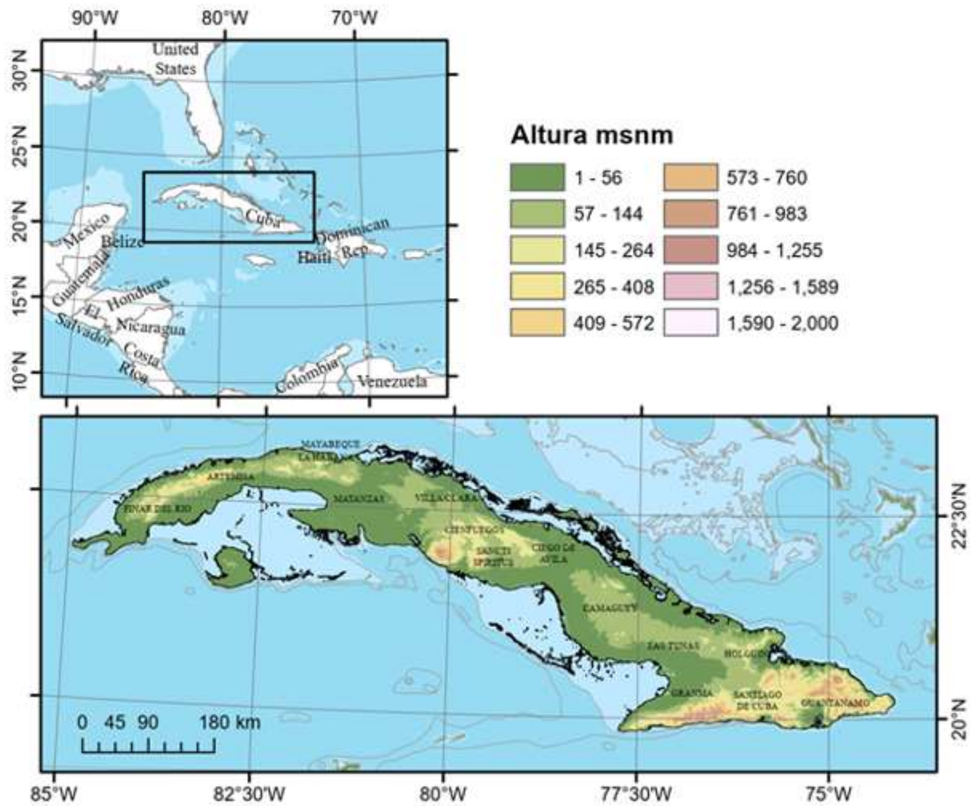

Fig. 1. *- Study area: Cuban Archipelago*

The WRF, mesoscale non-hydrostatic model, version v4.5 was used in the study. In the work, the relief, the land mask (ocean-soil interface), the type of cover and type of soil were defined as minimum static boundary data. These parameters are processed by the model preprocessing subsystem (WPS). National and global databases were used according to their availability and quality. Spatial databases with references in scientific journals were prioritized. In the case of national data not formally published, the official versions of the responsible organizations in the country were used. The high-resolution spatial databases of the best quality and most appropriate to the characteristics of the WRF were selected.

The research used the following national databases:

- The National Cadastre of the Republic of Cuba, scale 1:10 000 of the Department of Physical Planning Projects, 2018.

- The National Forest Cover Map, scale 1:100 000 of the State Forest Service, prepared by Estrada and collaborators in 2012.

- The Genetic Map of the Soils of Cuba, scale 1:250 000, by Hernández Jiménez and collaborators, Academia de Ciencias, 1971.

The definition of the land mask aims to enable the WRF equations to differentiate the ocean surface from the land surface. The land mask was generated as a binary map (1 = land surface, 0 = sea surface) with 1 arc second of spatial resolution. To define the land area, the National Cadastre was used, which serves as the basis for the National Soil Balance. This initial mask was complemented with data from the digital surface model (DSM) to reflect the emerged lands not collected from the national territory, generally small keys. This land mask was applied to all the data generated in the study (relief, cover type and soil type) to guarantee homogeneity. The land mask and other areas covered by water, such as reservoirs and lagoons, are identified by the WPS from the coverage data.

Relief is one of the determining boundary parameters in the performance of numerical meteorological models. The ALOS WORLD 3D digital surface model (DSM) was used, generated by the Japanese PRISM mission, with a horizontal resolution of one arc-second, approximately 30 meters at the equator (Tadono *et al.,* 2014). The selection of this model has the advantages of its global coverage and the representation of objects on the ground surface, such as vegetation and human modifications in the relief. Examples of the latter are earthquakes, tall buildings and roads. The limitations of this type of DSM are associated with possible errors in snowy areas or very steep and high slopes that are not of significant importance in the study area.

Due to the difference in scales of the national cadastre data with respect to other sources, a progressive adjustment process was carried out following the procedure described below:

1. Vector-raster conversion at 1 arc - second (approximately 30 m) spatial resolution.

2. Noise reduction by eliminating loose pixels and clusters smaller than approximately 1 km^2 in area.

3. Reclassification.

4. Data integration.

5. Application of sea/land mask.

In the research, the Capote and Berazaín (1984) classification of vegetation formations available as an attribute in the National Forest Map was used. The vegetation types were matched to the default cover classes in the WPS derived from the United States Geological Survey and Moderate Resolution Imaging Spectroradiometer (USGS24+1 and MODIS20+1, respectively) classifications. The USGS24+1 classification takes into account 24 cover types and the aqueous surface. MODIS 20+1 data are divided into 20 coverage classes and aqueous surface. In both cases the aqueous surface refers to lakes and watercourses, as the area occupied by seas and oceans is one of the classes. This class is not part of the original classification, in which the area covered by water does not differentiate between lakes and ocean. It is a class added only for the modeling system, so it was defined in all cases.

In the case of soil, the Genetic Soil Map of Cuba, scale 1:250 000, was used. Approximate equivalences with the WRF soil data were obtained from the information of the soil texture field of the database to match both classifications.

This process of land and cover equivalence allowed the reuse of the parameters already encoded in the WRF without the need to modify the modeling source code, which would have required a complex and expensive process of recertification of the numerical model.

The update of the WPS metadata of the model was carried out for the entire Cuban archipelago, guaranteeing the physical coherence: thermodynamics and hydrodynamics, of the meteorological variables that characterize the agroforestry ecosystems throughout the country.

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RESULTS AND DISCUSSION

Relief

Two DSMs of the area of interest were generated, at scales of 30 and 1 arc-seconds in the binary format used by the WRF (GEOGRID.EXE). The boundary conditions attribute table (GEOGRID.TBL) was updated to use this data by default.

Type of coverage

When comparing the classification of Capote and Berazaín with the USGS24 and MODIS20, coincidences are observed in terms of general and edaphoclimatic characteristics of several classes. These coincidences made it possible to directly associate a part of the classifications. Tables 1 and 2 show examples of the correlations identified between the rankings. In the annexes 1 and 2, the equivalences of the Capote and Berazain classifications with those of the USGS24 and MODIS20, respectively, used in the study are shown.

Table 1. *- Examples of the equivalence of Capote and Berazain classifications with those of the USGS24*

No	Capote & Berazain	Code	USGS24
41	Deciduous forest	eleven	Deciduous forest
3. 4	Typical cloud forest (1600-1900m)	13	Evergreen broadleaf forests
32	Microphyllous Semideciduous Forest	8	Charrascales
Four. Five	Holm oak	fifteen	Mixed forests
44	Swamp Thicket	18	forested wetland
38	*Pinus caribaea* pine forests	14	Evergreen Coniferous Forests
6	Broadleaf Plantations	fifteen	Mixed forests
26	Low altitude rainforest	13	Evergreen broadleaf forests
43	Natural sheets SL	10	Bed sheets
39	Bare and semi-naked areas	19	Barren or sparse vegetation

Table 2. *- Examples of the equivalences of the Capote and Berazain classifications with those of MODIS20*

No	Capote & Berazain	Code M20	MODIS20
41	Deciduous forest	4	broadleaf deciduous forest
3. 4	Typical cloud forest (1600-1900m)	2	Evergreen broadleaf forest
32	Microphyllous Semideciduous Forest	6	closed charrascals
Four. Five	Holm oak	5	mixed forest
44	Swamp Thicket	eleven	Permanent wetlands
38	*Pinus caribaea* pine forests	1	Evergreen coniferous forests
6	Broadleaf Plantations	5	Mixed forests
26	Low altitude rainforest	2	Evergreen broadleaf forest
43	Natural sheetsS. L	9	Bed sheets
39	Bare and semi-naked areas	16	Barren or sparsely vegetated

The forest groupings of Capote and Berazaín, which due to their complexities did not have direct correspondences with MODIS24 and USGS20, were grouped taking into account their majority structure or specific composition in the objective classifications. These groupings are described below:

a) Five of the Capote and Berazaín groupings were grouped in the Deciduous Forests class: "Coastal and subcoastal microphyllous evergreen forests (dry forest)"; "Typical mesophilic semi-deciduous forest on acidic soil"; "Mesophyllous semi-deciduous forest with fluctuating humidity"; "Coastal semi-desert thorny shrubland" and "Undifferentiated shrublands, mostly secondary and marabuzales, bushes and grasses with shrublands, very degraded and sparse secondary forests."

b) In evergreen broadleaf forest they were grouped: "The typical evergreen swamp forest"; "Mogote vegetation complexes"; "Charrascales" such as "Thorny xeromorphic scrub on serpentinite (cuabal)"; "Coastal and subcoastal scrubland with an abundance of succulents (coastal bush)" and the "calciphobic microphyllous evergreen forest".

c) Additionally, the "Calciphobic microphyllous evergreen forests" and the "Terrace

Vegetation Complex" were included in charrascales for both international coverage classifications.

The National Forest Map covers only forest areas, so the National Cadastre was used to complete the study area. In all cases, priority was assigned to the National Cadastre Map. Table 3 shows examples of the equivalences used between the type of use of the National Cadastre and those predetermined in the WRF. Annex 3 details the conversion used in the study.

Table 3. *- Examples of the equivalences of types of use between the National Cadastre and those of the USGS24 and MODIS20*

Type of use national cadastre	IDUuse	USGS24	MODIS20
Support for agricultural production	8420	1	13
Urban settlements	8010	1	13
Rural settlements	8020	1	13
Freeways	8110	1	13
public railway	8210	1	13
Other transportation facilities	8290	1	13
Various crops	1010	4	12
Deforested	5060	7	10
Idle surface (livestock)	4060	8	6
Coffee	2310	13	2
Cocoa	2410	13	2
Natural forests	5100	13	2

Two coverage databases were generated with the classes corresponding to USGS24+1 and MODIS20+1. Similar to the relief case, these cover type databases were transformed into the WRF executable binary format (GEOGRID.EXE). The result was updated to the corresponding attribute table. Two new tables were created available for modeling processes.

Soil type

In this case an equivalent raster resolution of 3 arc-seconds (approximately 90 m) was used. that appear in Table 4.

Table 4. *- Equivalences used from the database of the Genetic Map of the Soils of Cuba with the soil categories of the WRF*

Texture	WRF soil class	Texture	WRF soil class
Clay loam	9	Sand	1
Clay	12	Coalinitic clay	eleven
Clay-sandy loam- Sandy loam	7	sandy clay	10
Loam	6	loamy clay	8
Montmorillonitic clay	eleven		

The soil type database was transformed into the WRF executable binary format (GEOGRID.EXE). The result had the same treatment and generalization as those stated above. In this case the tables were updated using the same type of soil for the surface and the lower limit.

Post-processing and distribution of results

In total, 7 binary data packets were generated in a format compatible with the WRF WPS preprocessing system. This data is composed of a relief data package with 1 arc-second spatial resolution, two coverage packages with classes compatible with USGS24+1 at 1 and 30 arc-seconds, two coverage packages with classes compatible with MODIS20+1 at 1 and 30 arc-seconds, and two soil type data packages at 1 and 30 arc-seconds spatial resolution. Additionally, a specialized table was created for the configuration of the WRF preprocessing system (WPS_CUB.TAB) with the necessary parameters for its expeditious integration in the modeling. All of these data are integrated into the modeling system of the INSMET Center for Atmospheric Physics, and are available for use by the scientific community through contact with the authors.

When considering the contributions of the integration of high-resolution spatial databases to the WRF for the analysis of local climate in mountains of Cuba, the results achieved are consistent with a higher quality of static boundary conditions, as suggested in Varga and Breuer (2020) . It is noteworthy that, as a result of the process carried out, significant changes were identified in the distribution of coverage classes between the data provided as default in the WRF and those compiled in this research. In general, the integrated data present a distribution more in line with what is expected for the Cuban archipelago. For example, in the case of MODIS 20+1 classes, there is an increase of more than 5% in the areas of deciduous broadleaf forest, closed charrascal, savannas and permanent wetlands. This increase in area distribution was conditioned by the decrease in the area allocated to croplands and grasslands (8 and 10%) among others. The better definition of populated areas should be noted, which increased from practically zero to 3 % of the national territory. Figure 2 shows the class distributions in greater detail. It is of special interest that class 21 (lakes and rivers) remains practically unchanged, which is consistent with the capacity of the MODIS instrument to detect areas covered with water very accurately (Chu et al. 2021) , a capacity that does not It necessarily extends to regions covered with tropical vegetation and anthropized. In the latter case, it is significant that global classification algorithms do not appropriately recognize populated areas in the study area, possibly extending to developing countries outside of major cities, which may be due to structural differences with the most developed regions.

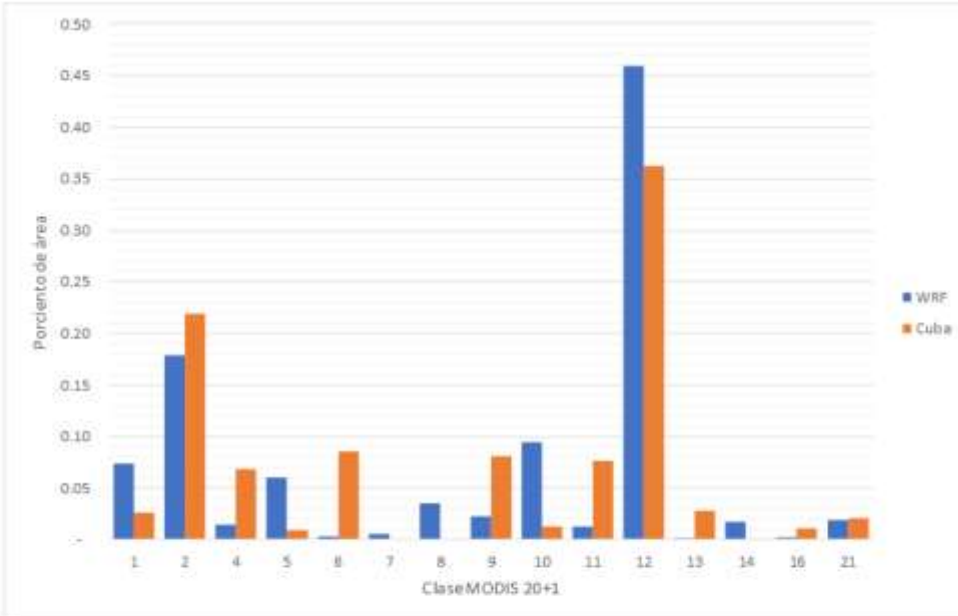

***Fig. 2. -** Comparison between the area proportion of the original MODIS20+1 data (WRF) and that generated in this research (Cuba). 1: Evergreen coniferous forest, 2: Evergreen broadleaf forest, 4: Deciduous broadleaf forest, 5: Mixed forests, 6: Closed charrascal, 7: Open charrascal, 8: Savannas with trees, 9: Savannas, 10: Grasslands, 11: Permanent wetlands, 12: Cropland, 13: Urban and Built-up, 14: Mosaic of cropland and natural vegetation, 16: Barren or sparsely vegetated, 21: Lakes/rivers. The latter is the additional class. The ocean is not included*

The results of the study, show a development in the definition of the distribution of cover and soil categories, with better identification of the land-sea interface. These changes are reflected in the increase in WRF performance at a local scale in mountain conditions identified by Peña-de la Cruz *et al. to the.* (2023). The first row of Figure 3, in cells b, presents examples of increasing the definition of the integrated data during the investigation. The second and third rows show the spatial resolution of the static boundary data in the WRF. In the second row, the default data in the model; in the third, the integrated high-resolution spatial data. In cell 1.1, the increase in the details of the geographical elements is evident, which corrects the definition of valleys, ravines and rivers in mountainous areas. Cell 2.1 allows us to observe the development between the surface databases, especially the better definition of the coastline and the variation in the distribution and type of cover. An example of the latter is notable in natural areas such as the mountain massifs and the Ciénaga de Zapata. In cell 3.1, a relatively common phenomenon can be seen in developing countries; the resolution of the supplied layer is even lower than 30 arcseconds, the resolution defined as default for this variable, soil type, in the WRF. This effect is common in spatial domains outside the most developed regions, where global data are scarcer and imprecise. In this case, to the increase in the spatial definition of the variable, greater class variability is added, with categories closer to the real conditions of the study area.

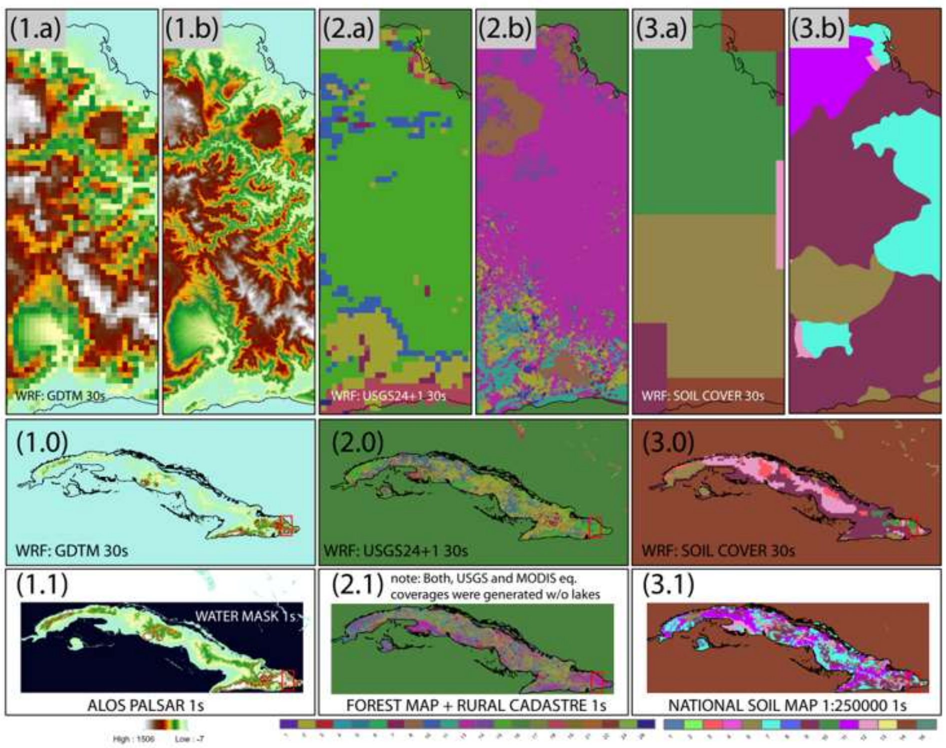

Fig. 3. - *Spatial databases in the WRF as static boundary conditions. The images in the 1st row: a, before and b, after the high-resolution spatial databases have been integrated. 2nd row: the default spatial databases in the model; 3rd row the integrated high-resolution spatial databases to the model*

The improvements identified strengthen the capacity of WRF-based modeling to integrate the geographic factors that shape the local climate, with benefits especially in mountainous regions. Among the direct applications of the study, we can highlight the strengthening of the modeling and forecasting of meteorological conditions that influence the appearance and development of forest fires, as noted by Zamora Fernández *et al. to the.* (2020; 2022).

Likewise, the results obtained can contribute to increasing the spatial resolution and effectiveness de los estudiosof the present and future local climate in the mountains. Similarly, the results obtained in this research will benefit risk management studies associated with forest fires, severe hydrometeorological events, climate variability and climate change, and other hazards related to the climate system that have affected Cuban agroforestry ecosystems.

CONCLUSIONS

The integration of a high-resolution spatial data set with the WRF model strengthens its capacity for the analysis of the geographic factors that shape local climate in the mountains. The integration of a high-resolution spatial data set with the WRF improves the model's ability for local-scale weather and climate monitoring and forecasting in the mountains of Cuba.

Thanks

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Annex 1. (Table 5).

***Table 5**. - Equivalencias de las clasificaciones de Capote y Berazain con las del USGS 24*

No	Capote & Berazain	Código	USGS 24
41	Bosque Caducifolio	11	Bosque caducifolio
34	Bosque nublado típico (1 600-1 900m)	13	Bosques siempreverdes de hojas anchas
35	Bosque pluvial montano (800-1 600m)	13	Bosques siempreverdes de hojas anchas
8	Bosque semideciduo mesófilo con humedad fluctuante	13	Bosque siempre verdes de hoja anchas
1	Bosque Semideciduo Mesófilo típico	11	Bosque caducifolio
16	Bosque semideciduo mesófilo típico sobre suelo ácido	11	Bosque caducifolio
32	Bosque Semideciduo Micrófilo	8	Charrascales
42	Bosque siempreverde de ciénaga bajo	13	Bosques siempreverdes de hojas anchas
7	Bosque siempreverde de ciénaga típico	13	Bosques siempreverdes de hojas anchas
2	Bosque siempreverde de mangles (manglar)	13	Bosques siempreverdes de hojas anchas.
17	Bosque siempreverde mesófilo de baja altitud (menor de 400m)	13	Bosques siempreverdes de hojas anchas
27	Bosque siempreverde mesófilo submontano (400-800m)	13	Bosques siempreverdes de hojas anchas
28	Bosque siempreverde Micrófilo calcifobo	8	Charrascales
4	Bosque siempreverde Micrófilo costero y subcostero (monte seco)	11	Bosque caducifolio
18	Bosques indiferenciados; mayoritariamente secundarios, seminaturales y ralos; plantaciones, arboledas, maniguas y matorrales	13	Bosque siempre verdes de hoja ancha
30	Charrascal Montano	8	Charrascales
10	Complejo de Vegetación de Mogote	13	Bosques siempreverdes de hojas anchas
36	Complejo de Vegetación de Terrazas	8	Charrascales
45	Encinar	15	Bosques mixtos

5	Herbazal de Ciénaga	13	Bosques siempreverdes de hojas anchas
3	Matorral costero y subcostero con abundancia de suculentas (manigua costera)	8	Charrascales
44	Matorral de Ciénaga	18	Humedal boscoso
21	Matorral Espinoso Semidesértico Costero	11	Bosque caducifolio
22	Matorral xeromorfo espinoso sobre serpentinita (cuabal)	8	Charrascales
29	Matorral xeromorfo subespinoso sobre serpentinita (charrascal)	8	Charrascales
19	Matorrales indiferenciados, mayoritariamente secundarios y marabuzales, maniguas y pastos con matorrales, bosques secundarios muy degradados ralos	11	Bosque caducifolio
40	Matorrales sobre Arenita	13	charrascales
35	Monte Fresco	13	Bosques siempreverdes de hojas anchas
38	Pinares de *Pinus caribaea*	14	Bosques siempre verdes de Coníferas
9	Pinares de *Pinus caribaea* y *Pinus tropicalis*	14	Bosques siempre verdes de Coníferas
23	Pinares de *Pinus cubensis*	14	Bosques siempre verdes de Coníferas
33	Pinares de *Pinus maestrensis*	14	Bosques siempre verdes de Coníferas
13	Pinares de *Pinus tropicalis* sobre arenas blancas	14	Bosques siempre verdes de Coníferas
12	Plantaciones de Pino	14	Bosques siempre verdes de Coníferas
14	Plantaciones de Pino Jóvenes	14	Bosques siempre verdes de Coníferas
6	Plantaciones Latifolias	15	Bosques mixtos
15	Plantaciones Latifolias Jóvenes	13	Bosques siempre verdes de hojas anchas
26	Pluvisilva de baja altitud	13	Bosques siempreverdes de hojas anchas
31	Pluvisilva Esclerofila Submontana sobre Mal Drenaje	13	Bosques siempreverdes de hojas anchas
24	Pluvisilva Esclerofila Submontana sobre Serpentinita	13	Bosques siempreverdes de hojas anchas

25	Pluvisilva Submontana sobre Comp. Metamórfico	13	Bosques siempreverdes de hojas anchas
43	Sabanas naturales S.L	10	Sabanas
37	Saladares	19	Estéril o escasa vegetación
39	Zonas desnudas y semidesnudas	19	Estéril o escasamente vegetado

Annex 2. (Table 6).

Table 6. *- Equivalencias de las clasificaciones de Capote y Berazain con las del MODIS 20*

No	Capote & Berazain	Código	MODIS 20
41	Bosque Caducifolio	4	Bosque caducifolio de hojas anchas
34	Bosque nublado típico (1 600-1 900m)	2	Bosque siempreverde de hojas ancha
35	Bosque pluvial montano (800-1 600m)	2	Bosque siempreverde de hojas ancha
8	Bosque semideciduo mesófilo con humedad fluctuante	4	Bosque caducifolio de hojas anchas
1	Bosque Semideciduo mesófilo típico	4	Bosque caducifolio de hojas anchas
16	Bosque semideciduo mesófilo típico sobre suelo ácido		Bosque caducifolio de hojas anchas
32	Bosque Semideciduo Micrófilo	6	Charrascales cerrado
42	Bosque siempreverde de ciénaga bajo	11	Bosque caducifolio de hojas anchas
7	Bosque siempreverde de ciénaga típico	2	Bosque siempre verde de hojas ancha
2	Bosque siempreverde de mangles (manglar)	11	Humedales permanentes
17	Bosque siempreverde mesófilo de baja altitud (menor de 400m)	2	Bosque siempreverde de hojas ancha
27	Bosque siempreverde mesófilo submontano (400-800m)	2	Bosque siempreverde de hojas ancha
28	Bosque siempreverde micrófilo calcifobo	6	Charrascales cerrados

4	Bosque siempreverde micrófilo costero y subcostero (monte seco)	4	Bosque caducifolio de hoja anchas
18	Bosques indiferenciados; mayoritariamente secundarios, seminaturales y ralos; plantaciones, arboledas, maniguas y matorrales	2	Bosque siempreverde de hojas ancha
30	Charrascal Montano	6	Charrascales cerrados
10	Complejo de Vegetación de Mogote	2	Bosque siempre verde de hojas ancha
36	Complejo de Vegetación de Terrazas	6	Charrascal cerrado
45	Encinar	5	Bosque mixtos
5	Herbazal de Ciénaga	2	Bosque siempreverde de hojas ancha
3	Matorral costero y subcostero con abundancia de suculentas (manigua costera)	6	Charrascales cerrados
44	Matorral de Ciénaga	11	Humedales permanentes
21	Matorral Espinoso Semidesértico Costero	4	Bosque caducifolio de hojas anchas
22	Matorral xeromorfo espinoso sobre serpentinita (cuabal)	6	Charrascales cerrados
29	Matorral xeromorfo subespinoso sobre serpentinita (charrascal)	6	Charrascal cerrado
19	Matorrales indiferenciados, mayoritariamente secundarios y marabuzales, maniguas y pastos con matorrales, bosques secundarios muy degradados y ralos	4	Bosque caducifolio de hojas anchas
40	Matorrales sobre Arenita	2	Charrascal abierto
35	Monte Fresco	2	Bosque siempreverde de hojas ancha
38	Pinares de *Pinus caribaea*	1	Bosques siempre verdes de coníferas
9	Pinares de *Pinus caribaea* y *Pinus tropicalis*	1	Bosques siempre verdes de coníferas
23	Pinares de *Pinus cubensis*	1	Bosques siempre verdes de coníferas
33	Pinares de *Pinus maestrensis*	1	Bosques siempreverdes de coníferas
12	Plantaciones de Pino	1	Bosques siempre verdes de coníferas

14	Plantaciones de Pino Jóvenes	1	Bosques siempre verdes de coníferas
6	Plantaciones Latifolias	5	Bosques mixtos
15	Plantaciones Latifolias Jóvenes	4	Bosque caducifolio de hojas anchas
26	Pluvisilva de baja altitud	2	Bosque siempreverde de hojas ancha
31	Pluvisilva Esclerofila Submontana sobre Mal Drenaje	2	Bosque siempreverde de hojas ancha
24	Pluvisilva Esclerófila Submontana sobre Serpentinita	2	Bosque siempreverde de hojas ancha
25	Pluvisilva Submontana sobre Comp. Metamórfico	2	Bosque siempreverde de hojas ancha
43	Sabanas naturales S.L	9	Sabanas
37	Saladares	16	Estéril o escasamente vegetado
39	Zonas desnudas y semidesnudas	16	Estéril o escasamente vegetado

Annex 3. (Table 7).

Table 7. *- Conversión de clases para el Catastro Nacional*

Tipo de uso del suelo catastro nacional	IDUso	USGS24	MODIS20	USGS24+1	MODIS20+1
Apoyo a la producción agropecuaria	8420	1	13	1	13
Apoyo a la producción silvícola		1	13	1	13
Asentamientos urbanos	8010	1	13	1	13
Asentamientos rurales	8020	1	13	1	13
Superficie ocupada por vertederos	8340	1	13	1	13
Instalaciones educacionales	8600	1	13	1	13
Instalaciones turística-recreativa	8700	1	13	1	13
Otras Instalaciones	8900	1	13	1	13
Autopistas	8110	1	13	1	13
Carreteras	8120	1	13	1	13
Avenidas	8121	1	13	1	13

Calles principales	8122	1	13	1	13
Calles secundarias	8123	1	13	1	13
Vías de interés específicos	8130	1	13	1	13
Ferrocarril público	8210	1	13	1	13
Ferrocarril cañero	8220	1	13	1	13
Ferrocarril industrial	8230	1	13	1	13
Otras instalaciones de transporte	8290	1	13	1	13
Aeropuertos	8240	1	13	1	13
Aeropuerto internacional	8241	1	13	1	13
Aeropuerto nacional	8242	1	13	1	13
Superficie de Instalaciones industrial	8320	1	13	1	13
Superficie de explotación minera	8330	1	13	1	13
Viveros y semilleros	2900	2	12	2	12
Caña de azúcar	3000	2	12	2	12
Cítrico	2210	2	12	2	12
Viveros y semilleros de cítricos	2920	2	12	2	12
Henequén	1910	2	12	2	12
Kenaf	1920	2	12	2	12
Tabaco	1410	2	12	2	12
Plátano	2110	2	12	2	12
Viveros y semilleros de frutales	2960	2	12	2	12
Otros cultivos temporales	1900	2	12	2	12
Pastos naturales	4100	2	12	2	12
Pastos y forrajes	4200	2	12	2	12
Forrajes temporales	4300	2	12	2	12
Producción pecuaria	8410	2	10	2	10
Arroz	1210	3	12	3	12
Cultivos varios	1010	4	12	4	12
Viveros y semilleros de pastos y forrajes	2980	4	12	4	12
Deforestada	5060	7	10	7	10
Otras no aptas	8000	7	10	7	10

Superficie ociosa (ganadería)	4060	8	6	8	6
Café	2310	13	2	13	2
Viveros y semilleros de café	2930	13	2	13	2
Cacao	2410	13	2	13	2
Viveros y semilleros de cacao	2940	13	2	13	2
Frutales	2290	13	2	13	2
Otros cultivos permanentes	2910	13	2	13	2
Viveros y semilleros de otros permanentes	2990	13	2	13	2
Bosques naturales	5100	13	2	13	2
Latifolias	5220	13	2	13	2
Coníferas	5210	14	1	14	1
Hídrica natural	7100	16	17	28	21
Embalses	7200	16	17	28	21
Canales	7300	16	17	28	21
Herbazal de ciénagas	7400	17	11	17	11

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