



Flood risk management and valley development: towards a balance between prevention and development

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Problematic

- Urban flooding, intensified by climate change and extreme rainfall variability, is a growing threat in cities, where soil sealing increases runoff and causes significant human and material damage. In Fez, a city developed along the tributaries of the Oued Fez, urbanization has weakened the natural absorption of floods, increasing the exposure of people and infrastructure.
- Traditional approaches to defining and managing valleys, based on historical hydrogeomorphology or standard modeling, are increasingly unsuitable. They overlook the complex interactions between natural processes and urban transformations.
- The failure or inadequacy of drainage infrastructures further amplifies urban vulnerability, underlining the urgent need to rethink the way valleys are integrated into urban planning and flood risk prevention. In this context, how can we ensure sustainable flood management in cities such as Fez?



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Presentation objectives :

- **Understand the causes of flooding in Fez:**
 - Climatic, topographical and hydrological factors
 - Impact of human activities (urbanization, sealing, etc.)
- **Analyze land-use planning failures:**
 - Urbanization in flood-prone areas
 - Insufficient drainage infrastructure
 - Poor consideration of risk in urban planning
- **Propose a sustainable land-use model for the valleys:**
 - Integration of flood risk into development planning
 - Preservation of natural retention areas
 - Development of resilient, sustainable urban planning



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Case study: Fez conurbation



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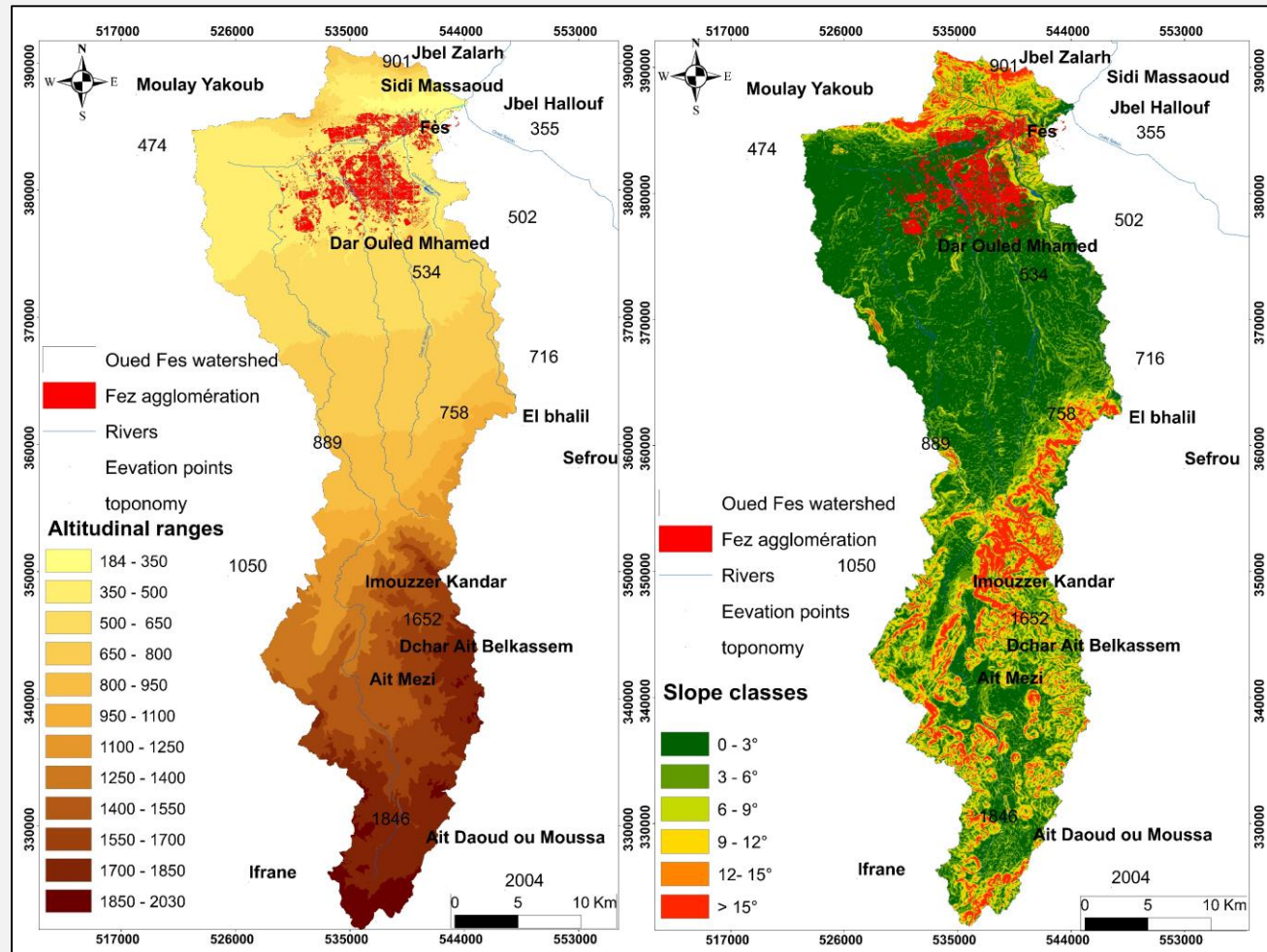
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Morphologie du bassin versant de l'oued Fès

- ✓ Part of the O. Fez watershed, which belongs to the Sebou watershed;
- ✓ Area of 879 km² covering;
- ✓ Located in a transition zone;
- ✓ Traversed by a dense hydrographic network;
- ✓ Contrasting topography: slopes $>12^\circ$ in the Middle Atlas / flat areas $<3^\circ$ in the Saïs plain.
- Configuration favoring flash floods upstream and accumulation downstream.



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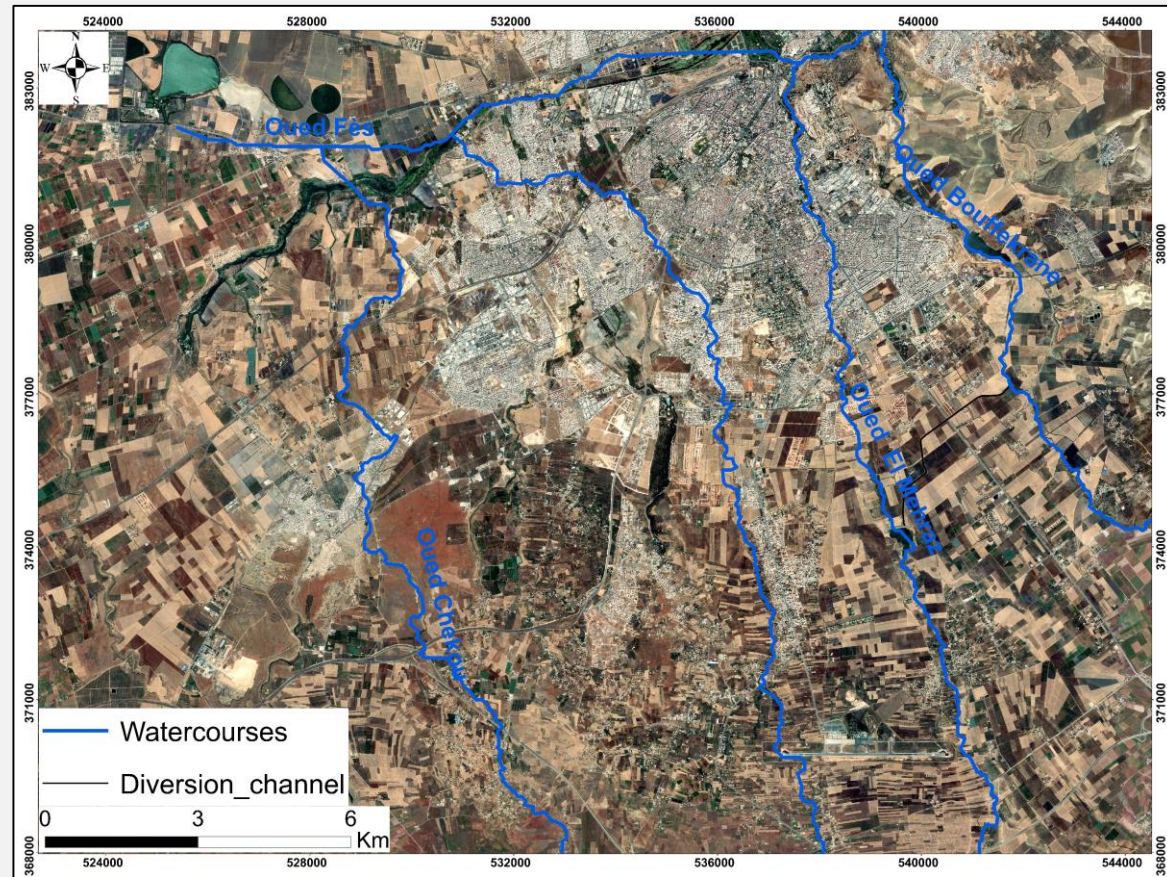
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Hydrographic network crossing the Fez conurbation

- The urban valleys of Fez develop around a dense hydrographic network, dominated by the Oued Fez and its affluents.
- They play a central role in the city's hydrological dynamics and spatial organization.
- Historically, they have contributed to
 - ✓ water supply;
 - ✓ irrigation of agricultural land;
 - ✓ natural flood control;
 - ✓ the creation of ecological breathing space within the urban fabric.
- Today, these functions are being severely altered by uncontrolled urban growth.



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Rapid urbanization and waterproofing



- The Fez urban area is undergoing rapid urban expansion, often with little supervision.
 - Buildings are encroaching on valley bottoms and flood plains, undermining the natural balance.
 - The spread of concrete and asphalt is leading to massive soil sealing.
 - This transformation greatly reduces the infiltration capacity of rainwater, which increases runoff and flow velocity.
 - The hydrographic network, already under strain, is subjected to increasing pressure.
- The result: entire neighborhoods become more exposed to flooding, particularly during periods of intense flooding.



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Anthropization is reflected in :

- ✓ Agricultural activity
 - ✓ Solid waste
 - ✓ Embankments
 - ✓ Infrastructures and developments
 - This anthropization has transformed valleys, which are areas naturally vulnerable to flooding, into high-risk areas.
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- Installations in flood-risk areas;
 - Occupation of riverbeds and valley bottoms;
 - Soil sealing;
 - Increased urban runoff.



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Technical measures for flood risk management in the Fez conurbation

Technical measures

Bled Al
Gâada dam

El Mehraz
(Moulay
Arafa) dam

Diversion
channel

Dhar El
Mehraz dike

Open or covered
drainage channel



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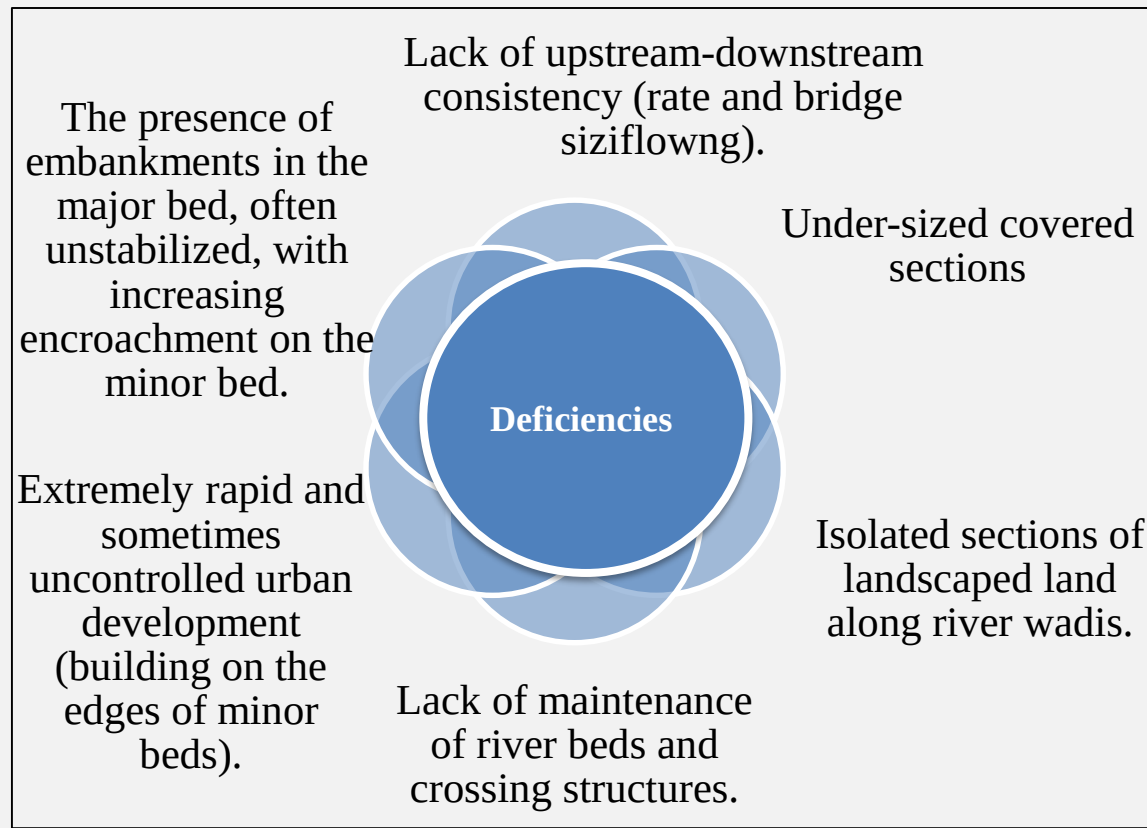


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Deficiencies in hydraulic structures

The river wadis concerned have a reduced transit capacity, unable to evacuate, with a few exceptions, decennial events without overloading the structures (which are generally undersized) and overflowing into adjacent areas. In addition, the risk of flooding is amplified by :



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Classic approaches to defining valleys



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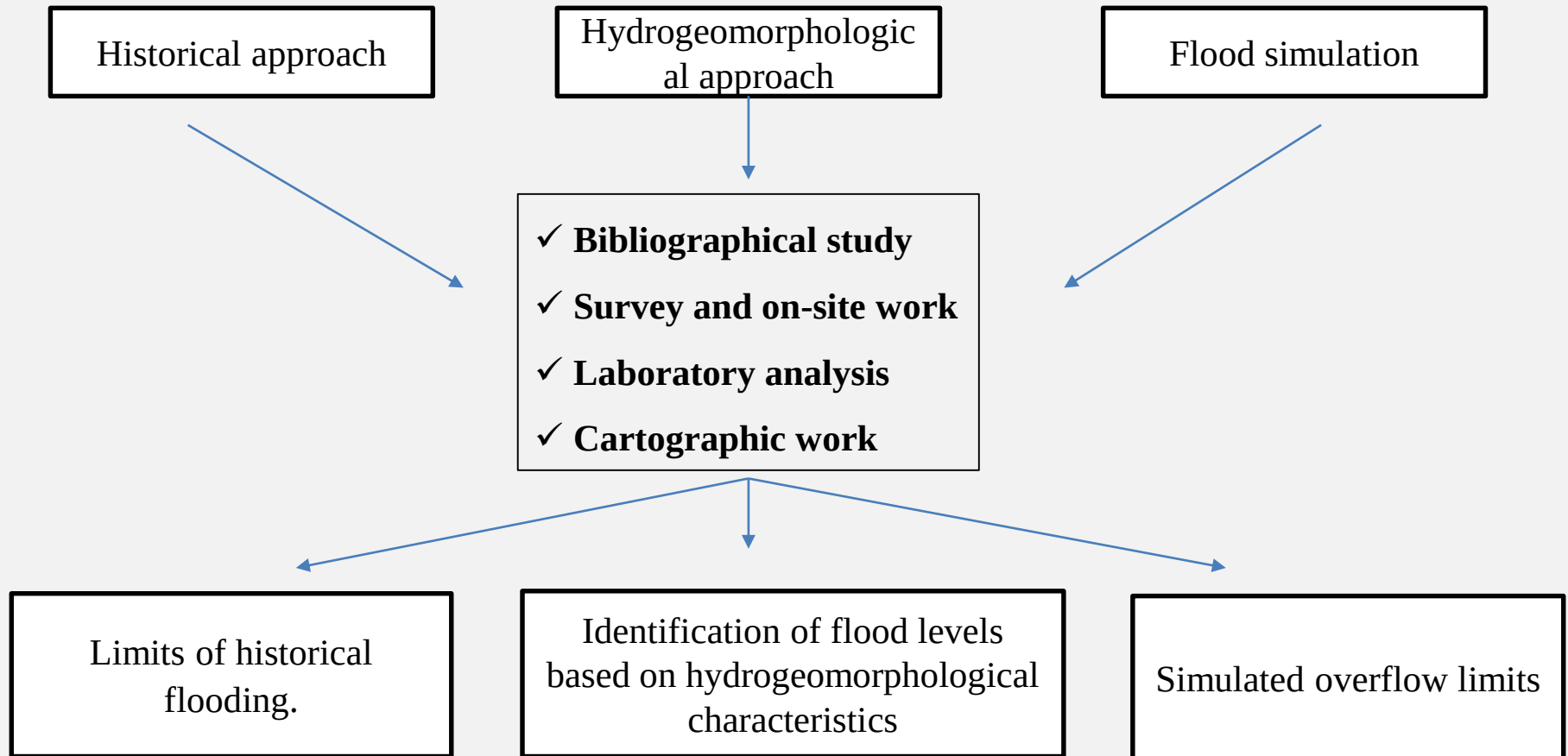
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Classical approaches to valley definition: principles and limitations



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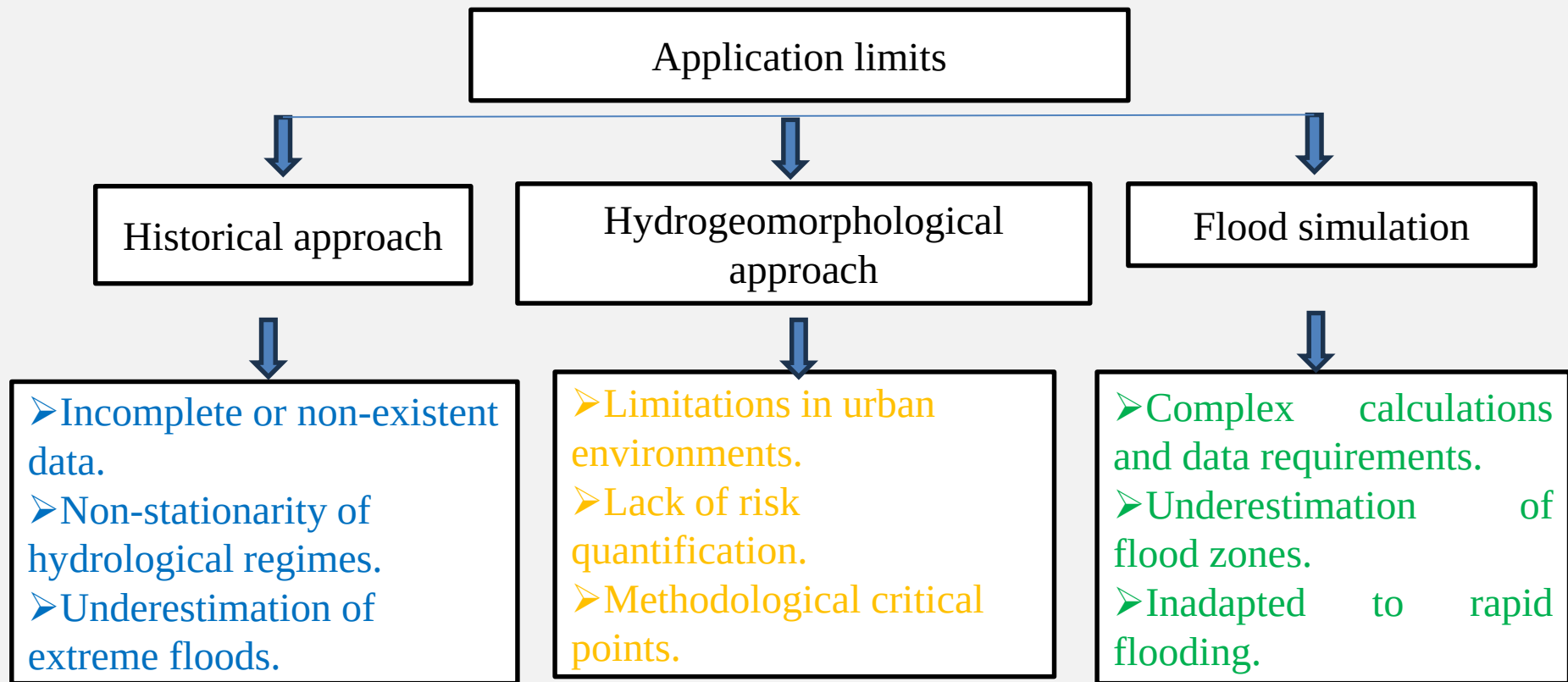
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Limits to the application of these approaches in the study area:

The application of these different approaches to the affluents of the Oued Fez crossing the Fez conurbation, present significant limits in the identification of flood zones and the management of urban flooding, particularly in complex contexts such as that of Fez.



Towards an integrated approach.



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Towards an integrated approach.

So far, different approaches have failed to answer our scientific questions.

An integrated approach combining the results of different flood risk assessment methods (historical, hydrogeomorphological and numerical modeling) is essential for effective and sustainable flood management in Fez.

- Principles of an integrated approach

- ✓ Cross-referencing of historical and geomorphological data and coupling with hydraulic modeling.
- ✓ Multi-sectoral and local participation.
- ✓ Consideration of climate and urban changes.
- ✓ Establish an urban resilience strategy.



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- Advantages of this approach
 - ✓ Provides a comprehensive, multidimensional view of risks.
 - ✓ Improves the accuracy of flood maps and the relevance of prevention measures.
 - ✓ Facilitates sustainable urban planning and the reduction of population vulnerability.
 - ✓ Provides greater capacity to anticipate and react to extreme events.



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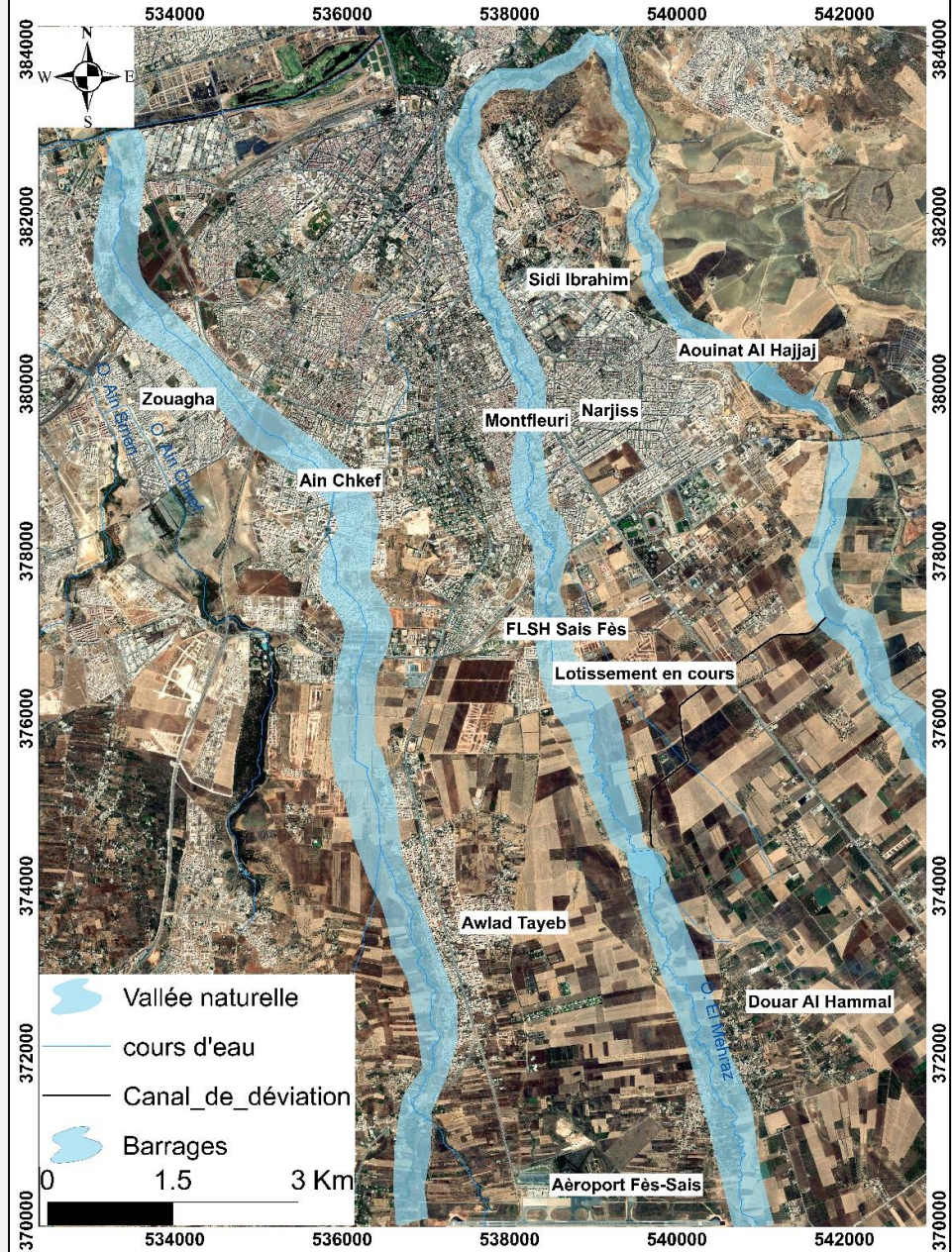


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By combining the results, we were able to:

- Establish the boundaries of the natural valley.
- Identify critical zones:
 - Precise delineation of major riverbeds and flood zones associated with floods of different return periods, with particular attention to vulnerable urban areas.
 - High-risk flood zones, particularly in alluvial plains and tributary confluences.
 - Identification of critical points linked to infrastructures (bridges, hydraulic structures) likely to amplify risks.



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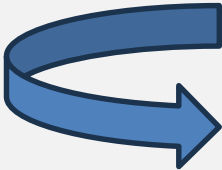
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These results call into question flood risk management and valley development methods, especially in urban environments.



New conception of the valley

- An essential natural infrastructure for risk management.
- An urban driving force for social cohesion and sustainable development.
- A space where the principles of sustainability, adaptability and resilience are integrated into development projects.



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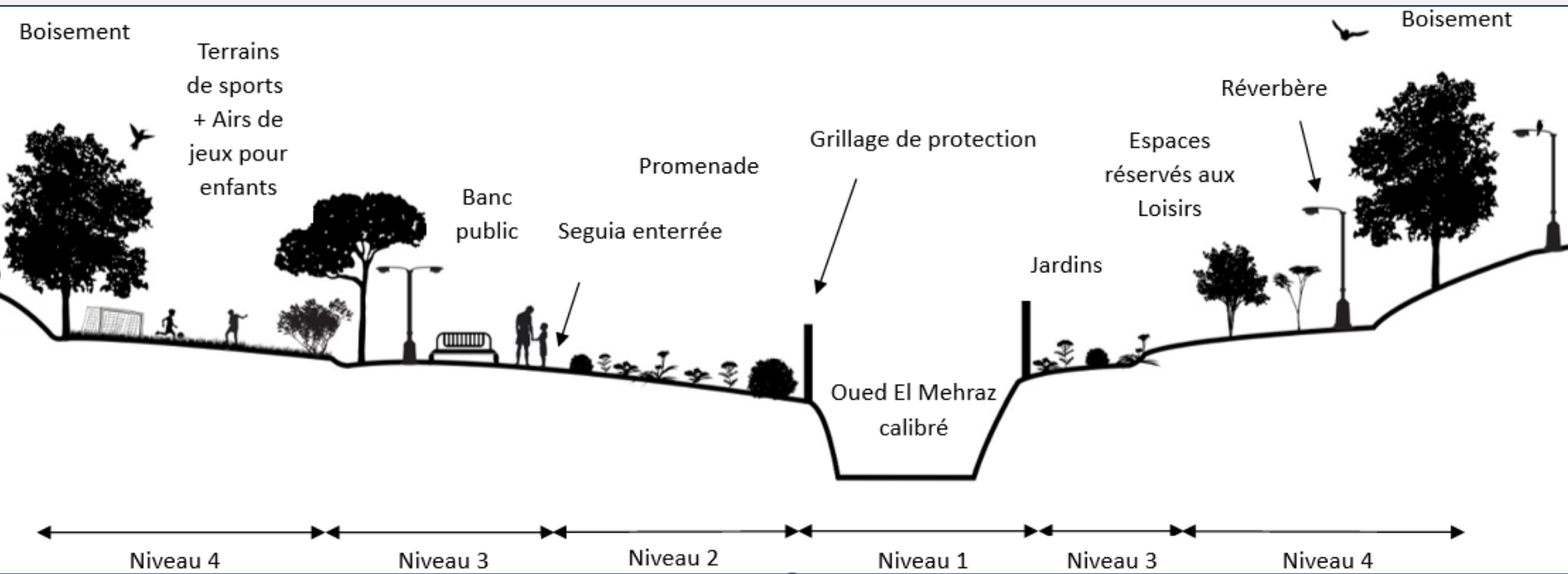
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Ecological development model and preservation of natural sites



- ✓ Restoration of flood plains;
- ✓ Creation of vegetated buffer zones;
- ✓ Creation of multifunctional public spaces.



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Recommendations and perspectives

- ✓ Apply nature-based solutions (NbS) for water management (urban humid zones, valleys, green roofs).
- ✓ Deploy artificial intelligence tools to predict floods and analyze spatial vulnerability.
- ✓ Use GIS and satellite data to monitor river dynamics and land use.
- ✓ Revise hydraulic standards to take account of future climate scenarios (RCP4.5, RCP8.5).
- ✓ Promote integrated “flood + development + quality of life” projects for resilient and attractive valleys.



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Conclusion

- Given the growing complexity of flood risks in Moroccan urban areas, the example of Fez illustrates the importance of an integrated, multidisciplinary approach. The combination of historical analysis, hydrogeomorphology, hydraulic modelling and citizen participation enables us to accurately identify critical areas and propose appropriate, sustainable and resilient solutions.
- The integration of risk management into land-use planning, the use of nature-based solutions and the promotion of participative and preventive management are essential levers for strengthening urban resilience. The enhancement of urban valleys, through the creation of ecological corridors and natural retention zones, offers concrete opportunities to reconcile urban development with the preservation of natural resources.
- The prospects opened up by this approach are promising for other Moroccan conurbations. By drawing on innovation, cross-sectoral coordination and the involvement of local players, it is possible to build safer, more sustainable cities that are better prepared for the climatic challenges of the future.



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