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LESLIE
LAND MANAGEMENT ENVIRONMENT & SOLID-WASTE

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MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

14.- Radar and Laser Remote Sensing

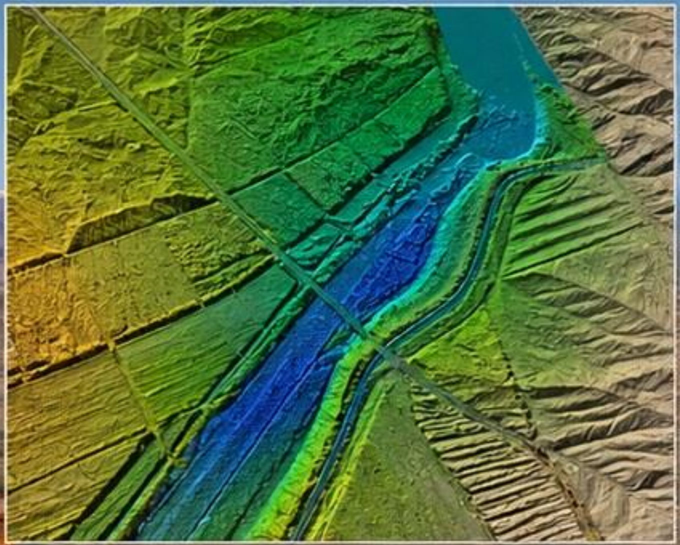
LiDAR Applications in Terrain Analysis

LM-W14-V96

LiDAR Applications in Terrain Analysis

Remote sensing for elevation, slope, drainage, floodplain and land management studies

Micro-credential: Remote Sensing and Land Management in Central Asia



Learning objectives

By the end of the lesson, students should be able to use LiDAR outputs for terrain analysis.

1. **Explain**

   how point clouds are converted into terrain models.

2. **Derive**

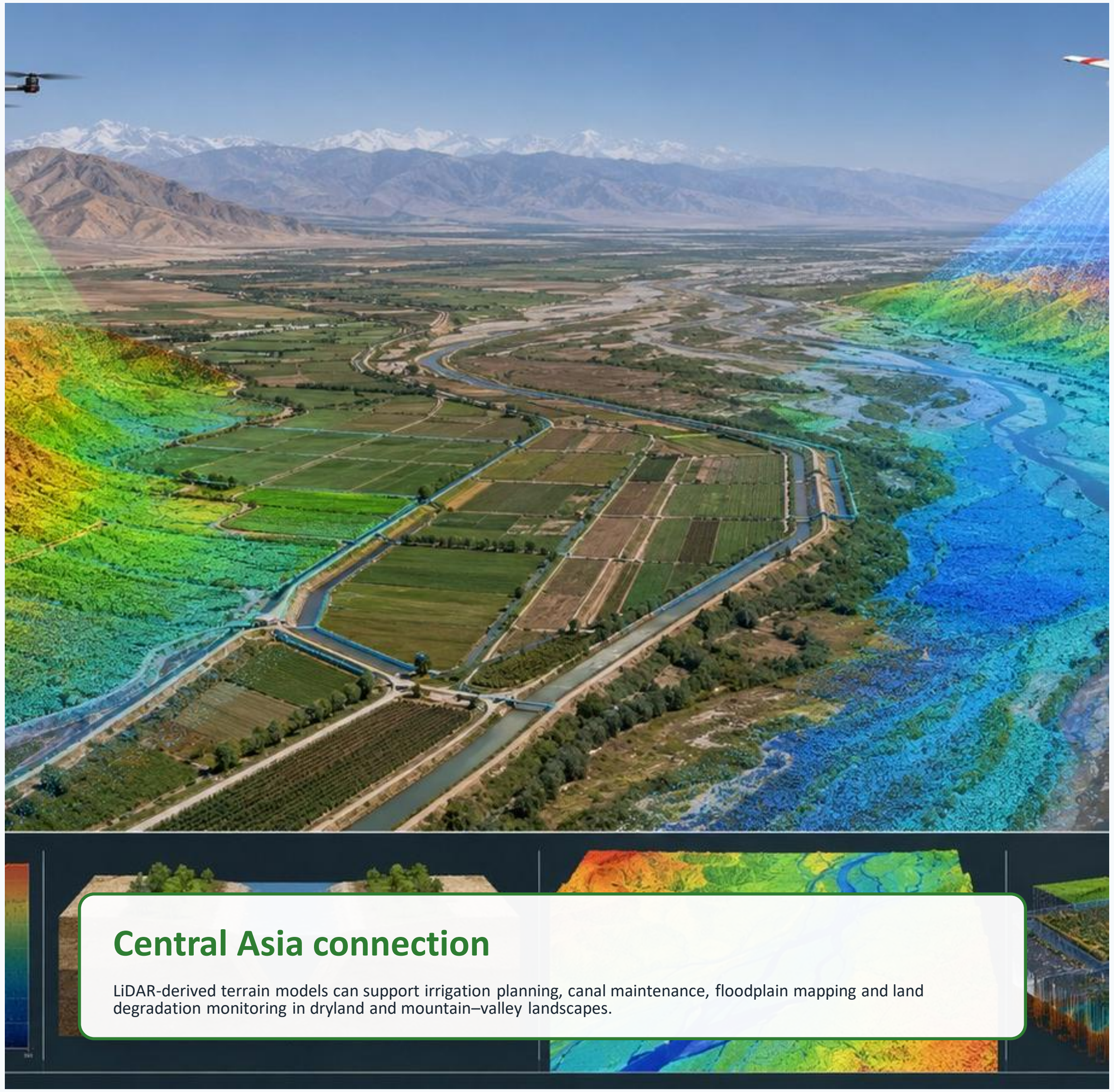
   slope, aspect, hillshade, curvature and drainage layers.

3. **Apply**

   LiDAR terrain products to erosion, flooding and irrigation problems.

4. **Evaluate**

   data quality, ground classification and limitations.

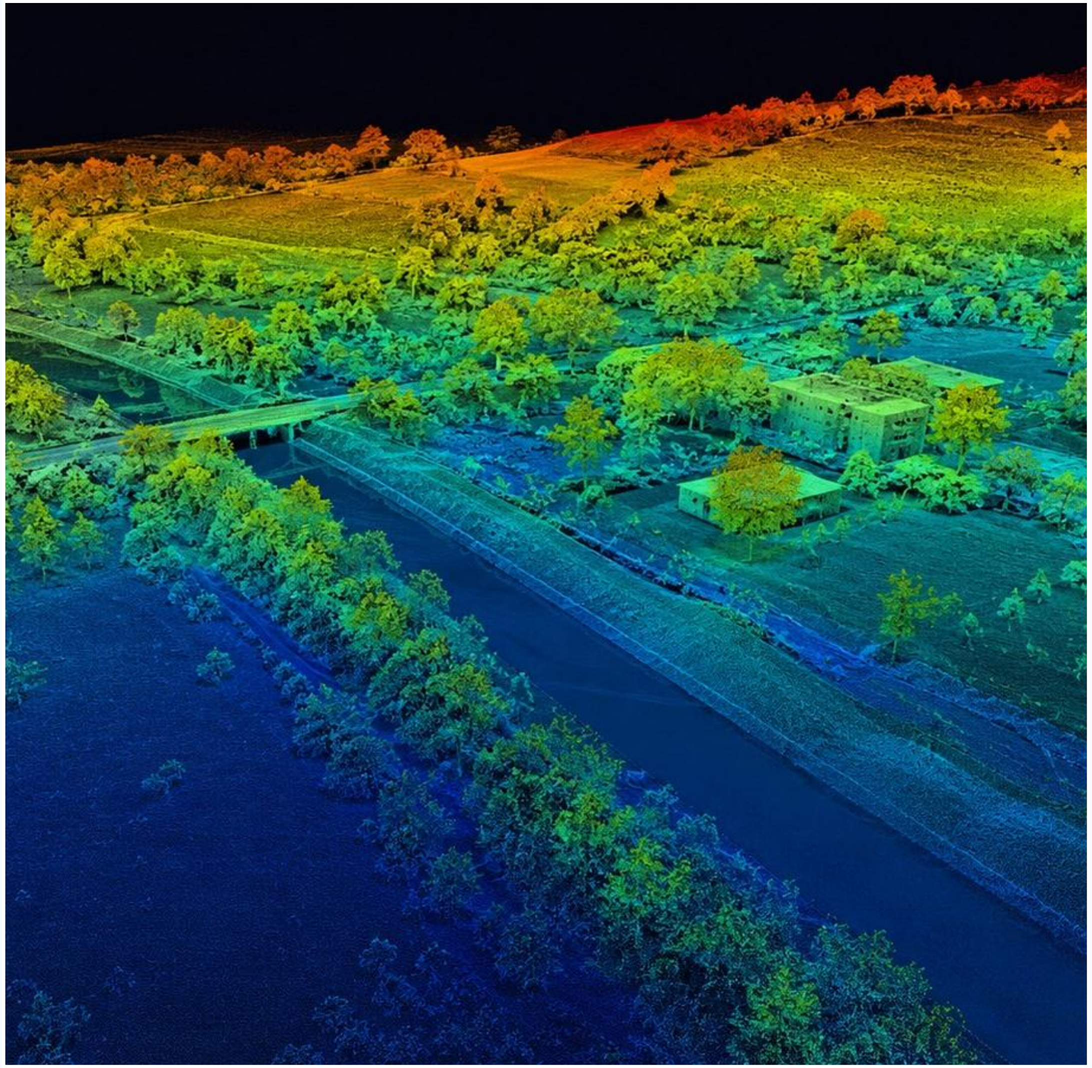


Central Asia connection

LiDAR-derived terrain models can support irrigation planning, canal maintenance, floodplain mapping and land degradation monitoring in dryland and mountain–valley landscapes.

Why terrain analysis needs LiDAR

Terrain is not only elevation; it controls water movement, land suitability, and geomorphic risk.



What LiDAR adds

Dense 3D measurements of the surface
Ability to separate ground, vegetation and built features
High-detail elevation for small channels, terraces and embankments

What terrain analysis extracts

Slope, aspect, hillshade and curvature
Drainage networks, watershed boundaries and flow paths
Floodplain, erosion and landslide indicators

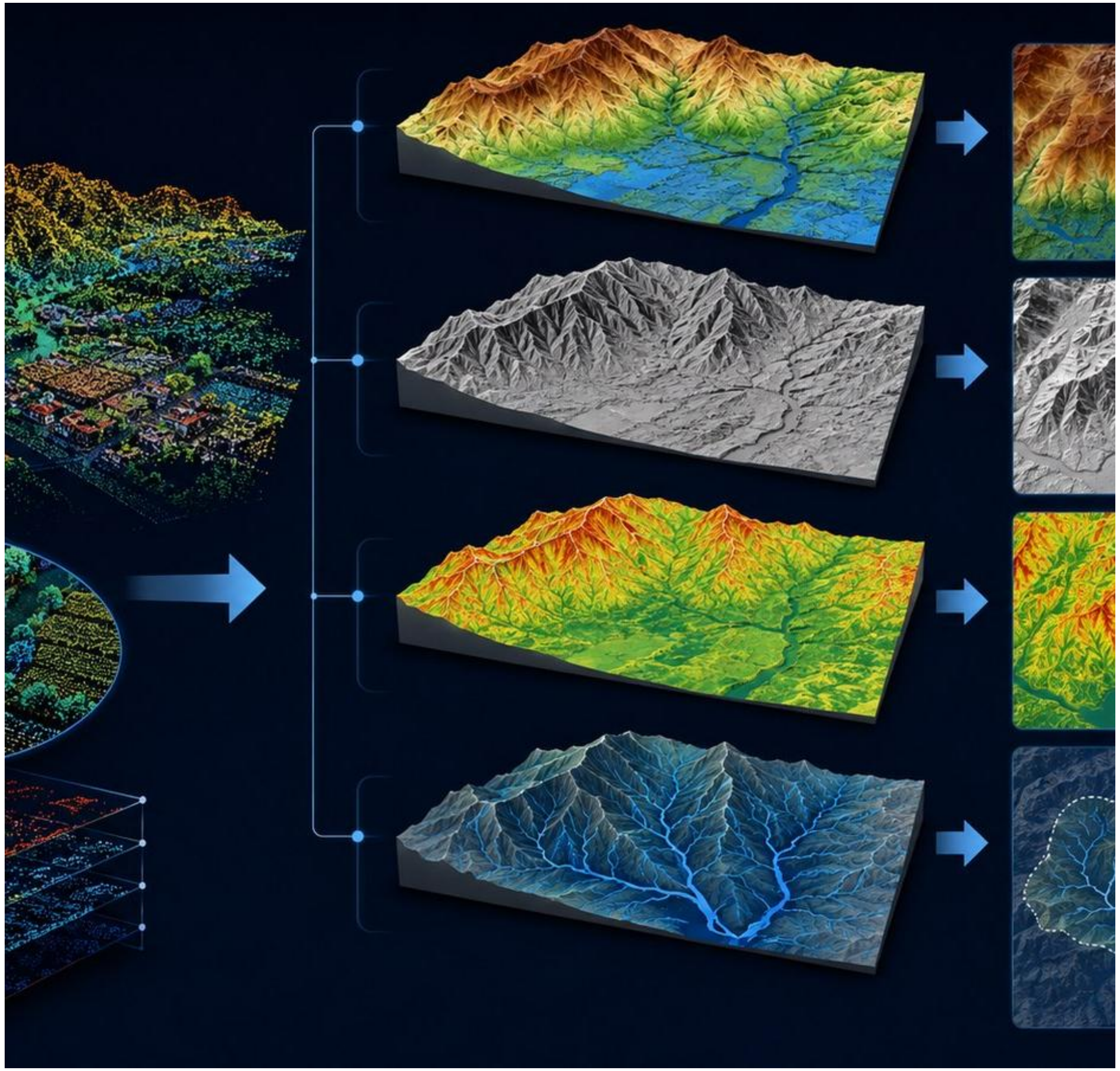
Why it matters for land management

Irrigation fields and canals depend on micro-relief
Infrastructure planning needs precise surface information
Environmental risks often start with topography and water concentration

LiDAR turns elevation into a decision layer.

From point cloud to terrain model

The main analytical task is to transform 3D points into useful terrain products.



1. Raw point cloud

XYZ points with intensity, return number and classification attributes.

2. Ground filtering

Separate bare-earth points from vegetation, buildings, bridges and noise.

3. Interpolation

Create DTM/DEM grids and remove gaps or irregularities.

4. Derivatives

Generate hillshade, slope, aspect, curvature and hydrological layers.

Core terrain products from LiDAR

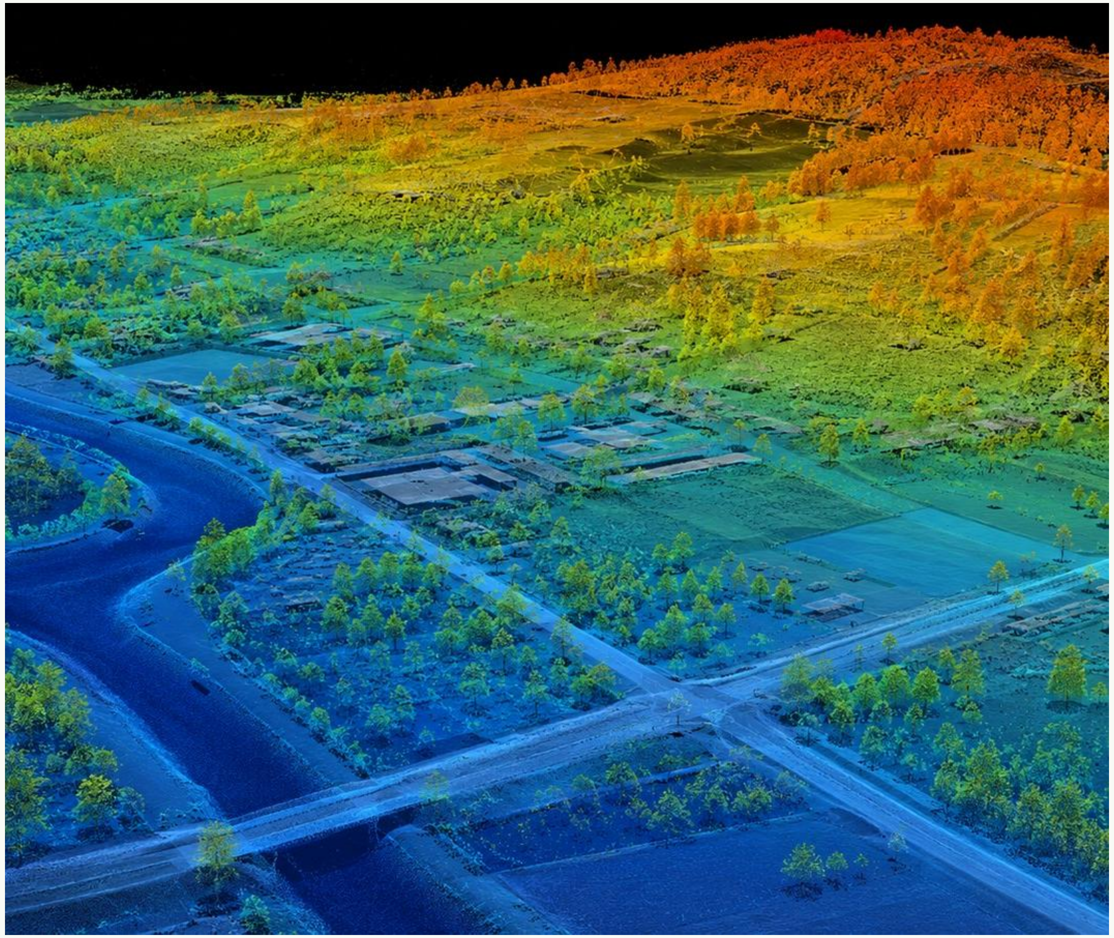
Different models represent different parts of the landscape.

DSM
Digital Surface Model
Top of canopy, buildings and objects

DTM
Digital Terrain Model
Bare earth after ground classification

DEM
Digital Elevation Model
General elevation grid; usage depends on data source

CHM
Canopy Height Model
DSM minus DTM, useful for vegetation height



Key rule
For terrain analysis, always check whether the product is bare-earth terrain or includes surface objects.

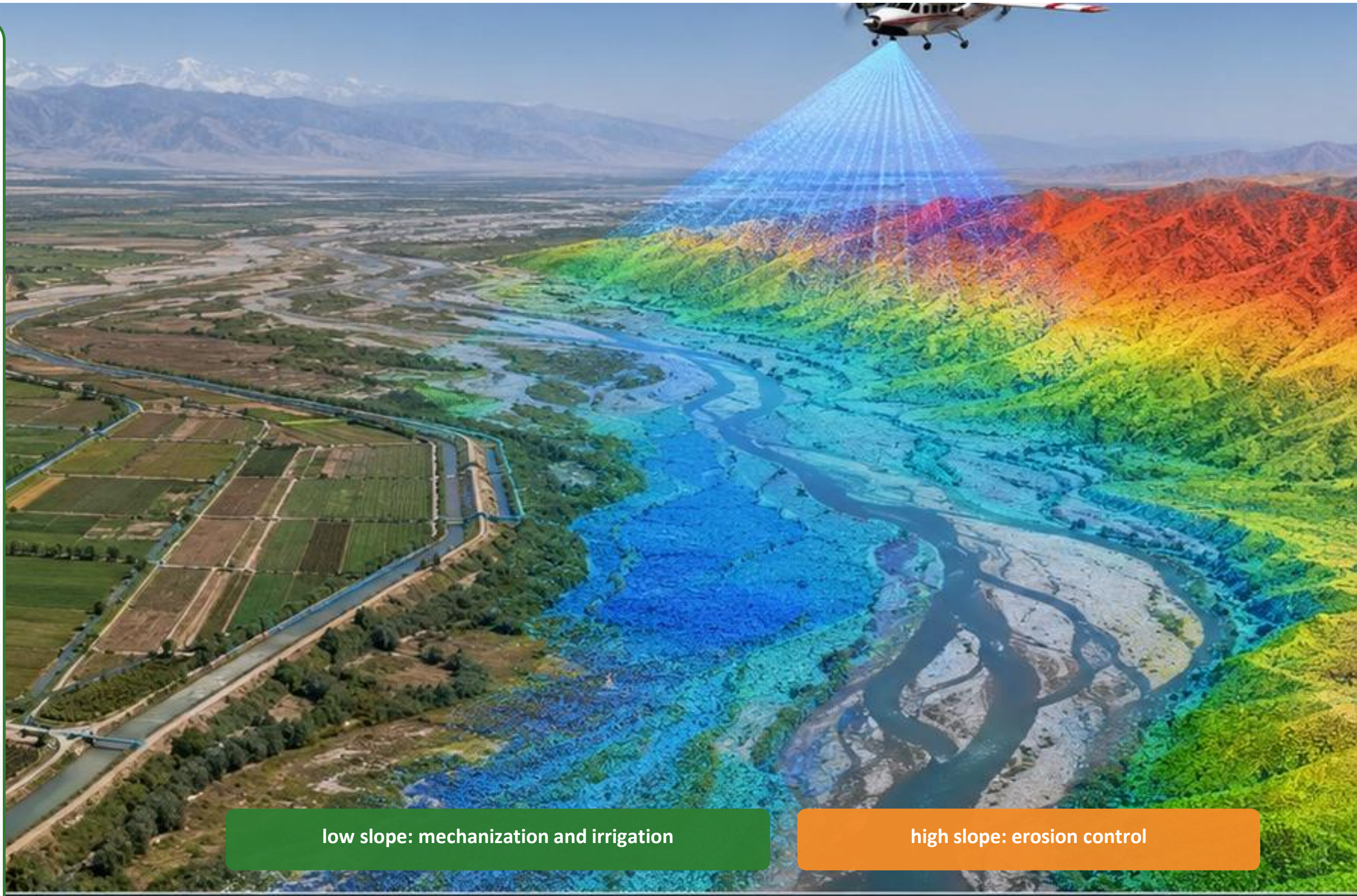
Slope analysis for land suitability

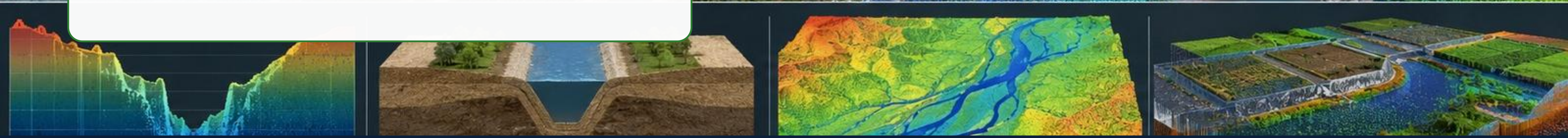
Slope controls runoff speed, erosion potential, machinery access and irrigation feasibility.

Typical slope-based decisions

Identify areas suitable for irrigated fields
Detect steep slopes with high erosion risk
Locate stable routes for canals, roads and pipelines
Prioritize terracing, drainage or conservation works

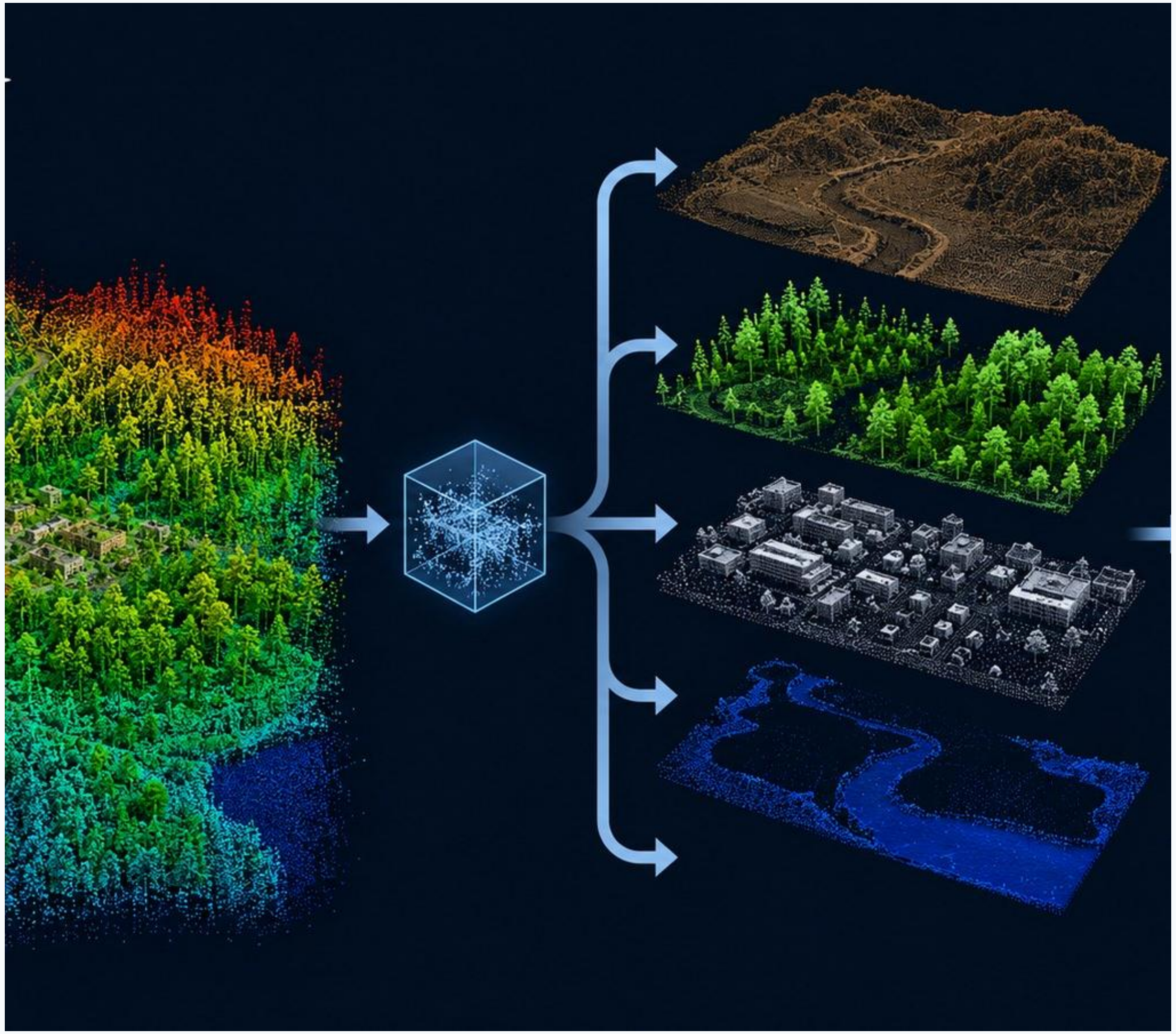
Result: a slope map becomes a practical filter for land-use planning.





Aspect, hillshade and terrain visibility

LiDAR terrain models help us read the landscape as a 3D surface.



Aspect

Direction of slope exposure
Important for microclimate, soil moisture and vegetation patterns

Hillshade

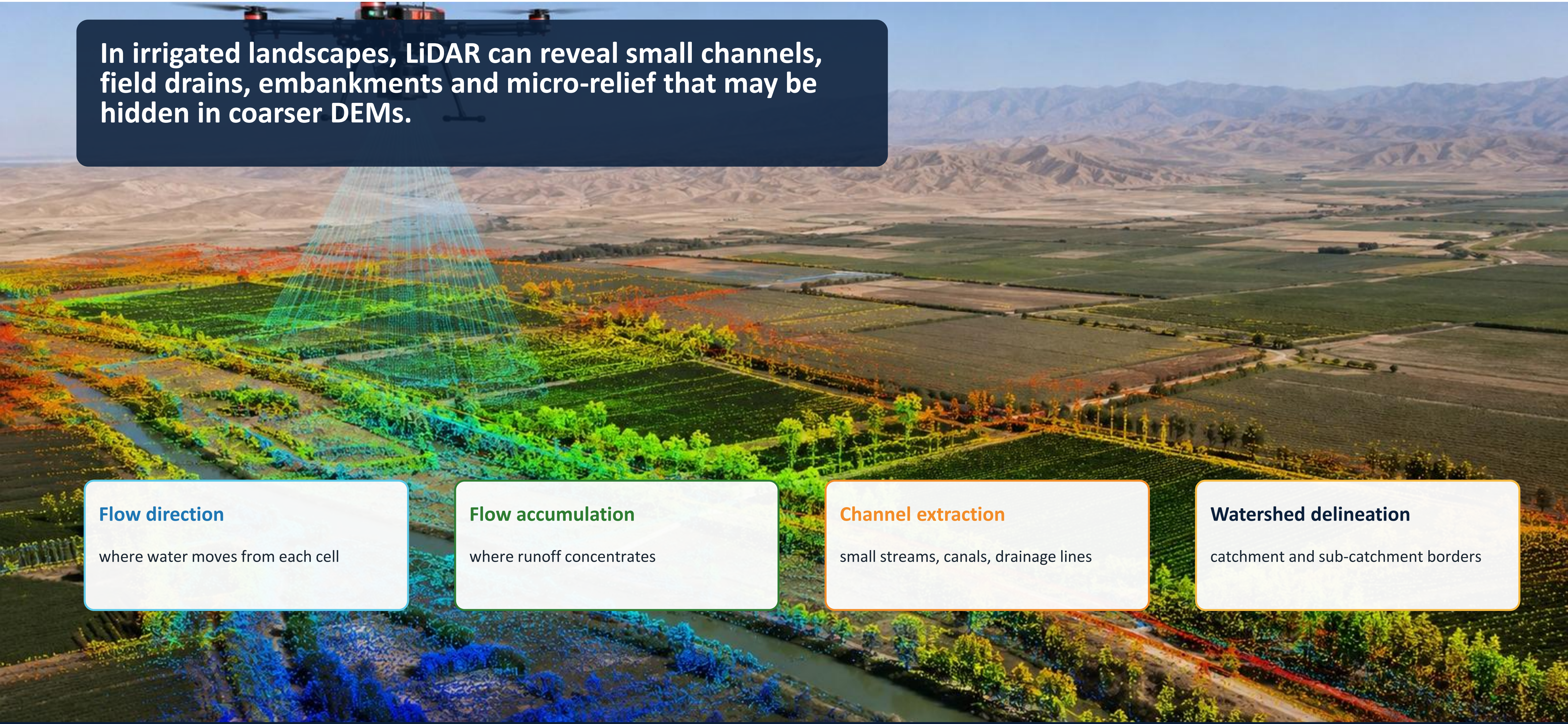
Shaded relief derived from elevation and illumination angle
Useful for interpreting small channels, terraces and earthworks

Curvature

Identifies convex and concave landforms
Supports erosion, deposition and water-concentration analysis

Drainage networks and watershed boundaries

Fine-scale elevation improves hydrological terrain analysis.



In irrigated landscapes, LiDAR can reveal small channels, field drains, embankments and micro-relief that may be hidden in coarser DEMs.

Flow direction

where water moves from each cell

Flow accumulation

where runoff concentrates

Channel extraction

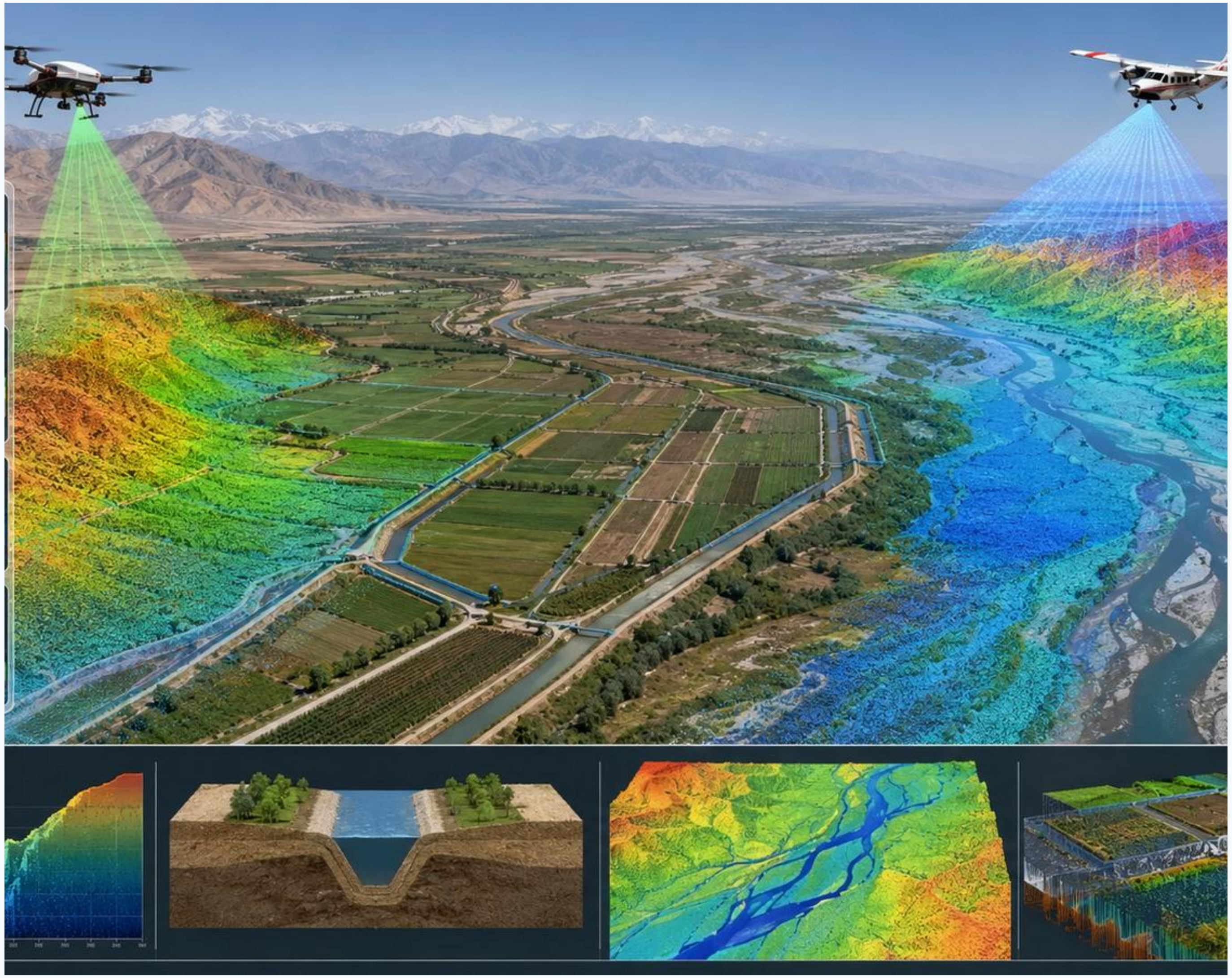
small streams, canals, drainage lines

Watershed delineation

catchment and sub-catchment borders

Floodplain and channel analysis

Terrain detail is essential for mapping where water may spread, pond or erode banks.



LiDAR-based floodplain indicators

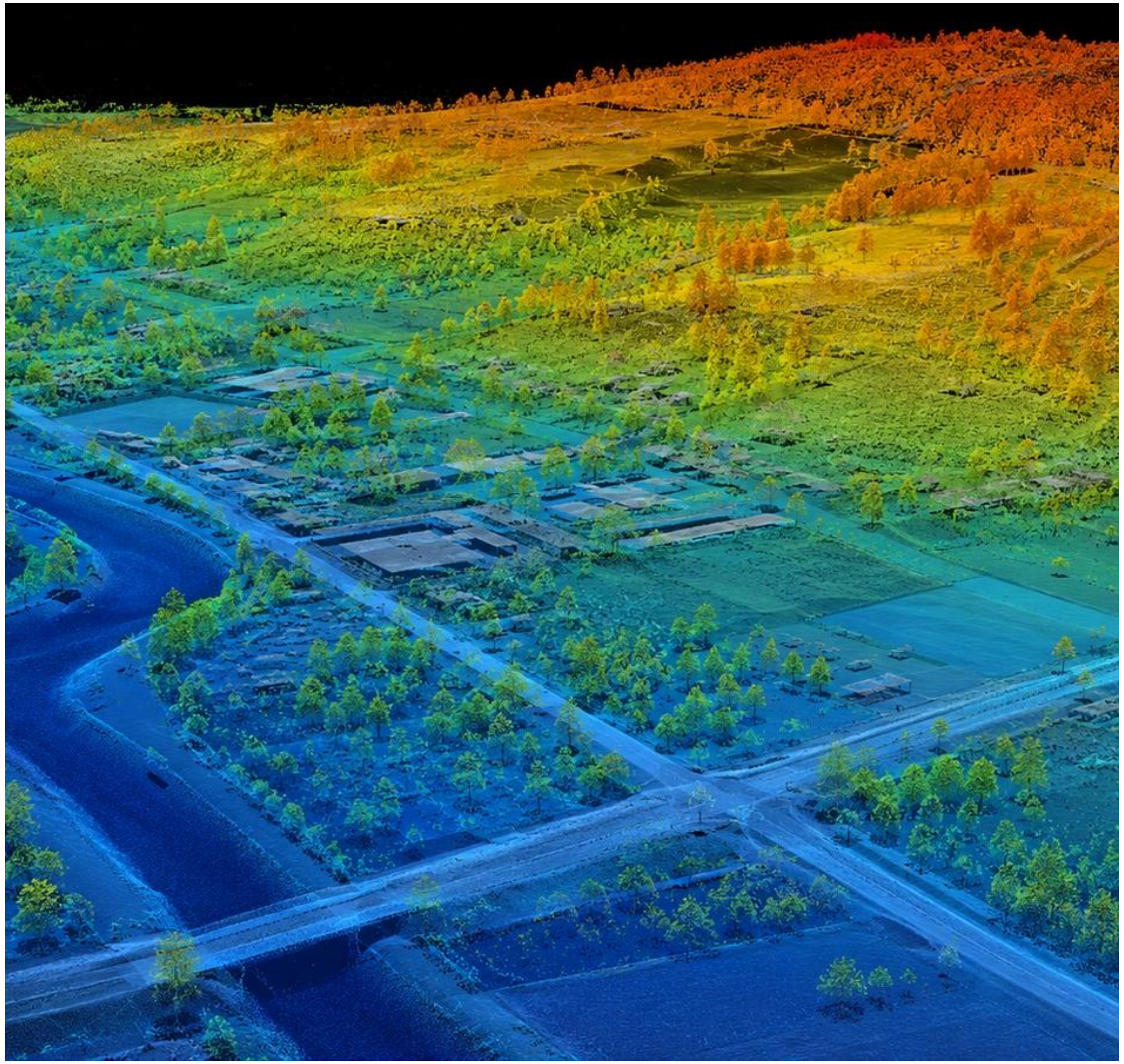
- **Low-lying cells** — potential inundation zones
- **Levees and embankments** — barriers or weak points
- **Channel geometry** — bank height and cross-section
- **Flow paths** — surface connectivity during events

Land management value

Better terrain data supports safer settlement planning and more realistic flood risk zoning.

Erosion, landslides and geomorphic risk

LiDAR helps identify where terrain form can create land degradation hazards.



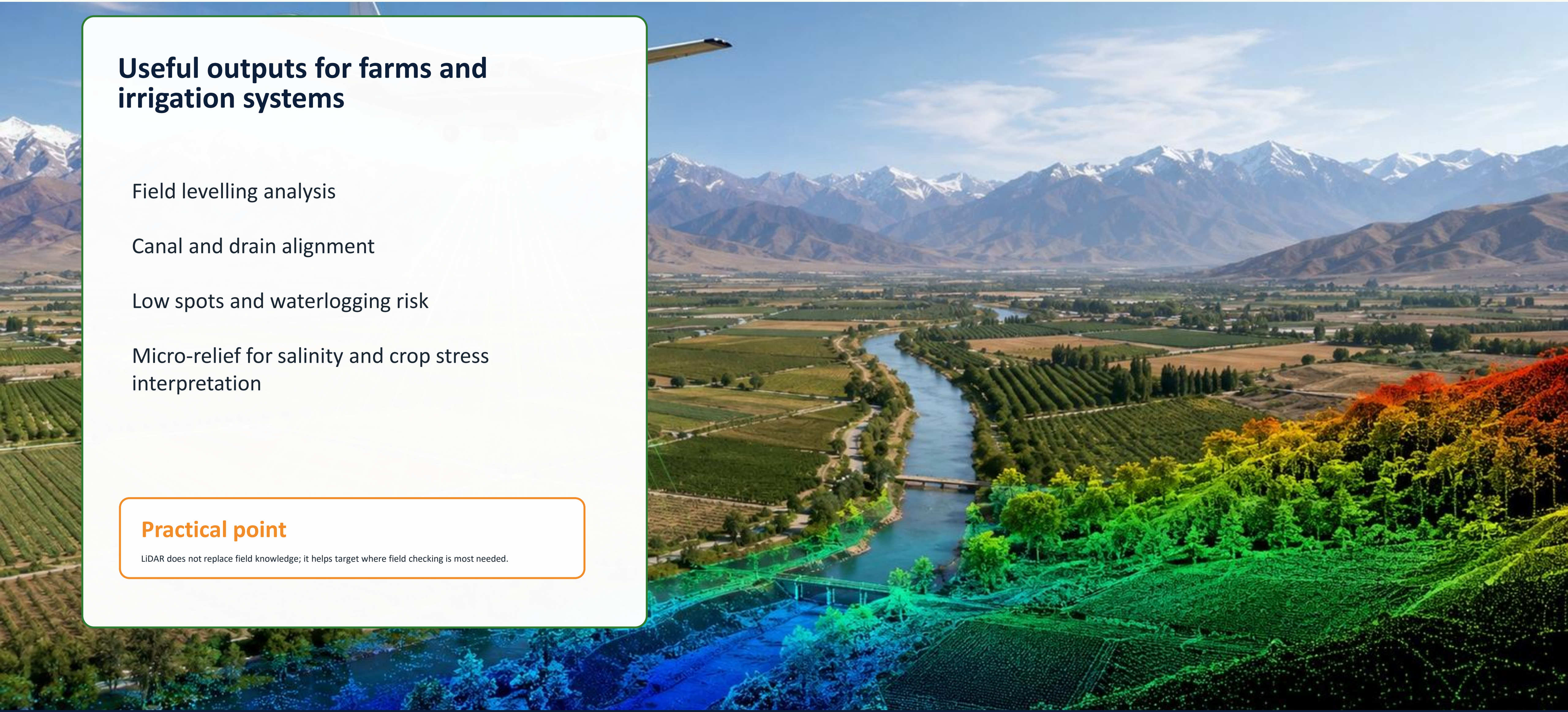
Terrain clues used in risk mapping

- ✓ **Steep slope + bare soil** — higher erosion susceptibility
- ✓ **Concave hollows** — runoff concentration and gully initiation
- ✓ **Scarps and breaks in slope** — possible landslide signatures
- ✓ **Road cuts and canal banks** — localized instability and sediment sources

Outcome: a terrain-based risk layer for field verification and mitigation planning.

Agriculture and irrigation terrain analysis

In irrigated areas, small elevation differences can strongly affect water distribution.



Useful outputs for farms and irrigation systems

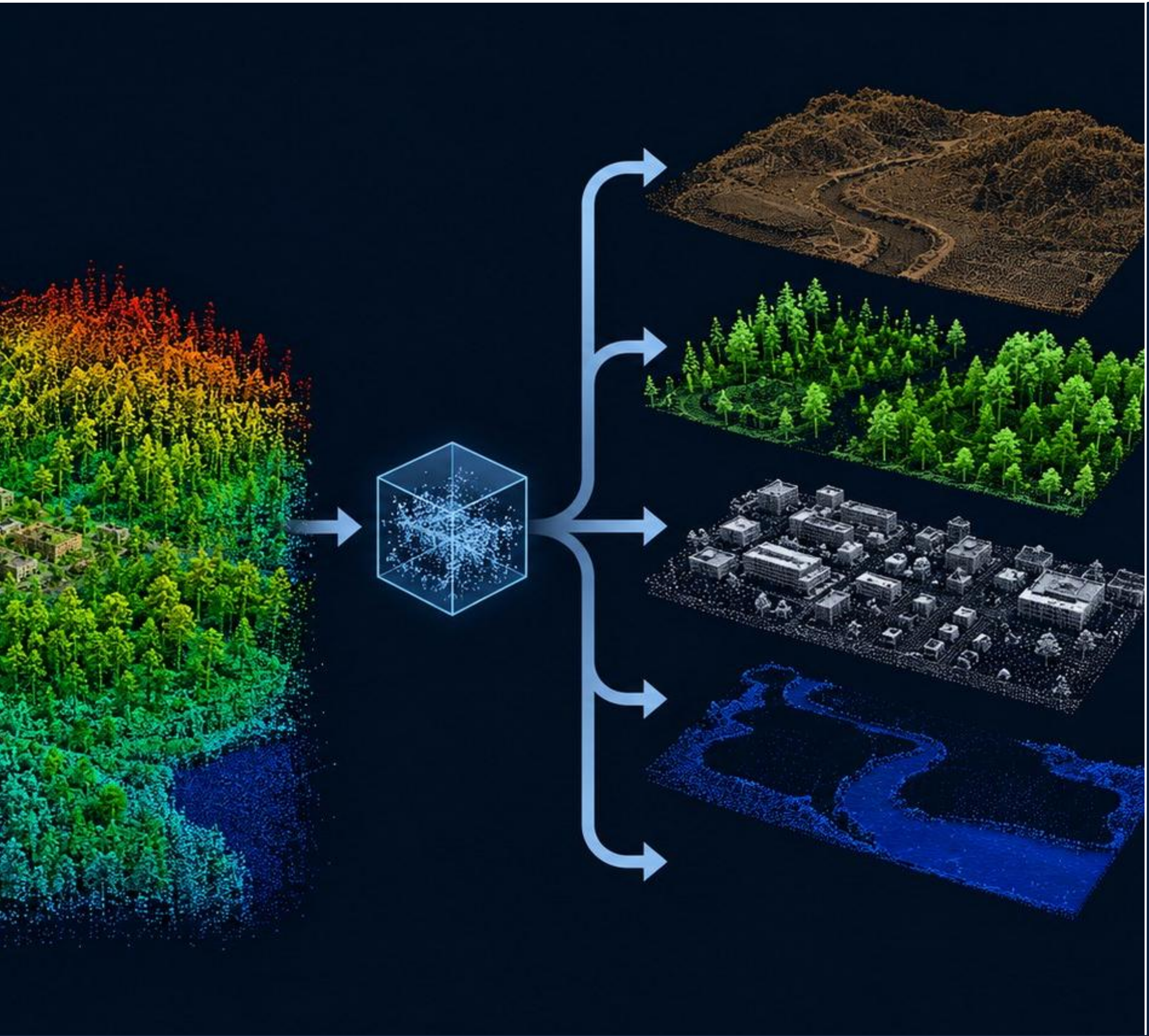
- Field levelling analysis
- Canal and drain alignment
- Low spots and waterlogging risk
- Micro-relief for salinity and crop stress interpretation

Practical point

LiDAR does not replace field knowledge; it helps target where field checking is most needed.

Infrastructure and engineering surfaces

Terrain products support the safe design and maintenance of linear infrastructure.



Engineering uses

Road corridors	cuts, fills, drainage crossings and visibility
Canals and drains	slope continuity, embankments and leakage-prone depressions
Pipelines and power lines	terrain clearance and construction constraints
Urban expansion	buildable terrain, flood exposure and surface drainage

The strongest results come when LiDAR terrain data are integrated with design standards, cadastral layers and field inspection.

GIS workflow for terrain analysis

A practical sequence that can be implemented in ArcGIS Pro, QGIS or similar GIS software.

1
Download / import LAZ or LAS point cloud

→

2
Check projection, vertical datum and metadata

→

3
Classify ground points and remove noise

→

4
Create DTM/DEM grid at suitable resolution

→

5
Derive slope, aspect, hillshade and flow

↓

Quality control before interpretation

Check gaps, noise, low vegetation confusion, water surfaces, edge artifacts and interpolation errors. Always compare terrain products with imagery and field knowledge.

Good practice

Document coordinate system, point density, acquisition date, classification method and grid cell size for reproducible analysis.

Strengths, limitations and good practice

LiDAR is powerful, but the interpretation must respect data quality and landscape context.

Strengths

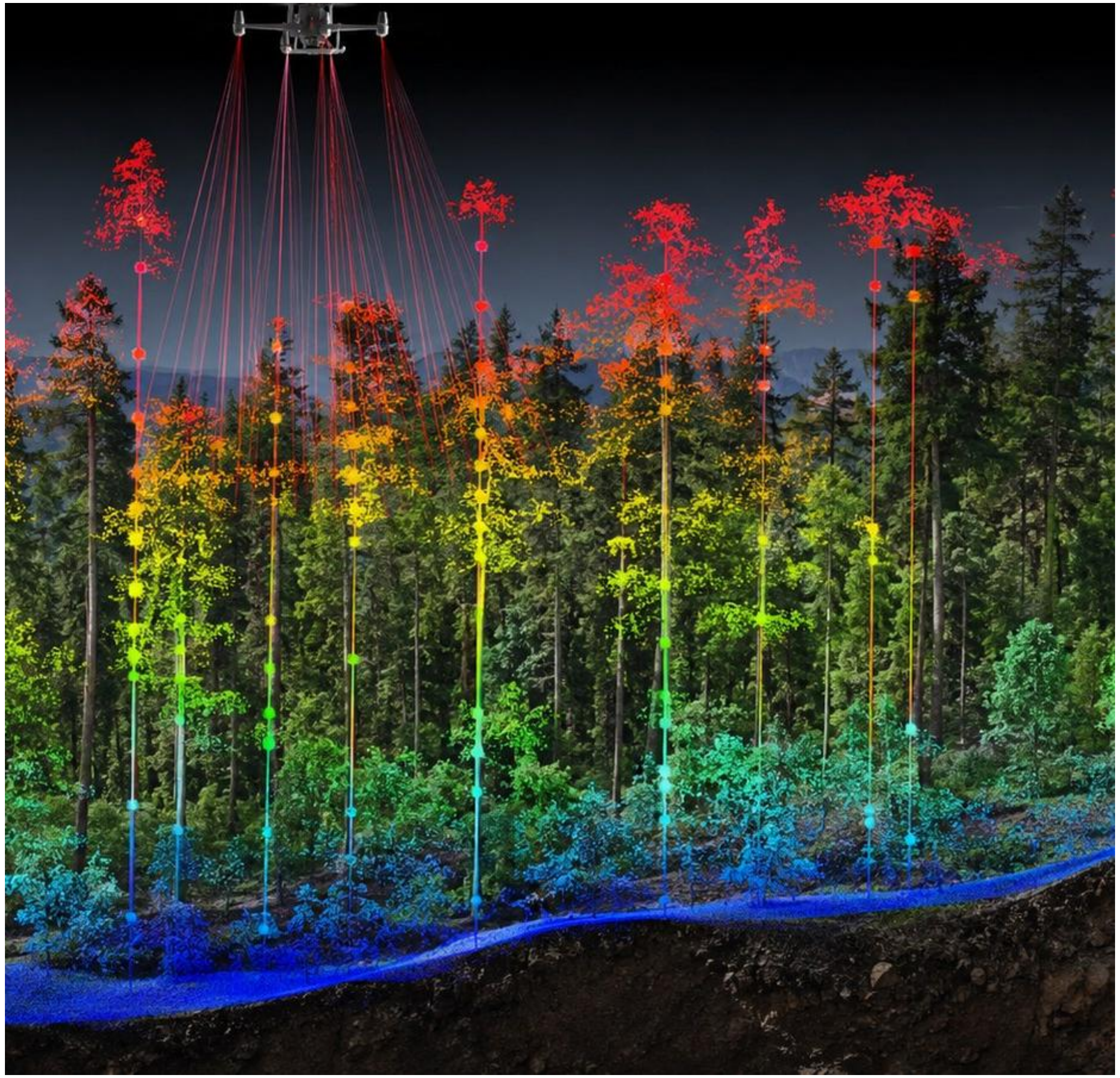
High spatial detail for micro-topography
Canopy/ground separation when classification is good
Accurate derivatives for slope, flow and engineering analysis

Limitations

Vegetation, buildings and bridges can confuse bare-earth models
Water surfaces may create gaps or weak returns
Different datasets may use different vertical datums and quality levels

Good practice

Use metadata and accuracy reports
Validate results with field checks or trusted reference data
Choose resolution based on the decision problem, not only on data availability



Summary and references

Key messages for independent study and further reading.

Summary

LiDAR point clouds can be transformed into terrain models for practical analysis.

Slope, aspect, hillshade, curvature and drainage layers support land management decisions.

Applications include irrigation planning, floodplain analysis, erosion risk, infrastructure design and landscape monitoring.

Quality control is essential: metadata, classification, datum and field validation matter.

Selected references

USGS. 3D Elevation Program (3DEP): elevation data, lidar point clouds and DEM products.
USGS. 3DEP Standards and Specifications: lidar and IfSAR as primary sources for modern elevation data.
NOAA Digital Coast. Coastal Topographic and Topobathymetric LiDAR data access resources.
NASA Earthdata. GEDI LiDAR instrument: forest canopy height, vertical structure and surface elevation.
Shokirov, Sh.S., Musaev, I.M., & Akbarov, M.S. (2015). Masofadan zondlash. Tashkent.
ASPRS. LAS Specification and positional accuracy standards for digital geospatial data.

Independent study: compare a LiDAR-derived hillshade with a standard DEM for the same area and identify which terrain details become visible.

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