Using Satellite Technology to Deliver Saudi Arabia's Vision 2030

Saudi Arabia's Vision 2030 is a comprehensive, strategic framework launched by the Kingdom to reduce its dependence on oil and build a more diverse, innovative and environmentally sustainable economy. The goal is to develop its public-service sectors such as health, education, technology, infrastructure, recreation and tourism. Satellite technology is fundamental to deliver the aspirations of the Vision 2030 reforms and in 2020, the country announced plans to invest $2.1 billion in its space program. Saudi Arabia has bought and developed satellites, launched by NASA, Roscosmos, Arianespace, SpaceX and CNSA, and the Kingdom is currently building a constellation of SAR small-sats.

Over the last decade, Saudi Arabia's urban population has increased by over 2% annually because of natural growth, internal migration from rural areas to avail of better opportunities and living standards, as well as an increase in foreign labour to service the oil industry and construct Vision 2030's smart cities. This expansion has placed enormous strain on infrastructure, resources, traffic congestion and pollution, severely impacting the local the environment. To inform future planning, satellite imagery together with GIS are being used to monitor urban growth, detect and measure changing land use, identify unregulated construction and plan new infrastructure based on demographic needs in cities such as Riyadh, Jeddah, NEOM and Dammam. When combined with socio-economic data, planners can predict future trends, such as where population growth will require new housing, schools, green spaces and healthcare facilities. This integrated approach ensures efficient resource allocation and supports disaster management and conservation by identifying areas where urban expansion risks harming sensitive ecosystems such as drainage basins and wadis.

Figure 1 : Satellite Images of The Line [Visit Saudi.com].

Saudi Arabia receives only 50 to 150 mm of rain each year and satellite technology provides real-time and long-term data to monitor, plan and conserve precious water resources. Optical and multispectral imaging can detect and track changes in reservoir levels, river widths and flow dynamics.

Water scarcity and sustainable agriculture are major challenges for the Kingdom and satellite technology is being used improve food security and better farming. Passive microwave sensors are used to measure Earth's natural emissions to determine surface moisture content as damp soil emits less radiation due to its higher dielectric constant. Similarly, active SAR transmits pulses and captures the reflected backscatter, which is higher from wet soils due to higher conductivity and smoother surface from moisture. These insights are used to manage land use and sustainability, monitor the onset of drought, inform irrigation planning, estimate crop yields and assess flood risks. ESA freely makes available global soil-moisture maps for public use and analyses.

Satellite-based evapotranspiration (ET) measures crop water evaporation and transpiration allowing farmers to manage irrigation to improve yields, reduce water waste, pumping costs and comply with local regulations. Saudi Arabia's Ministry of Environment, Water and Agriculture (MEWA) uses ET to monitor and optimise agricultural water use, improve sustainability and enforce regulations limiting over-irrigation. When combined with GPS co-ordinates, growers know precisely where to irrigate to conserve water.

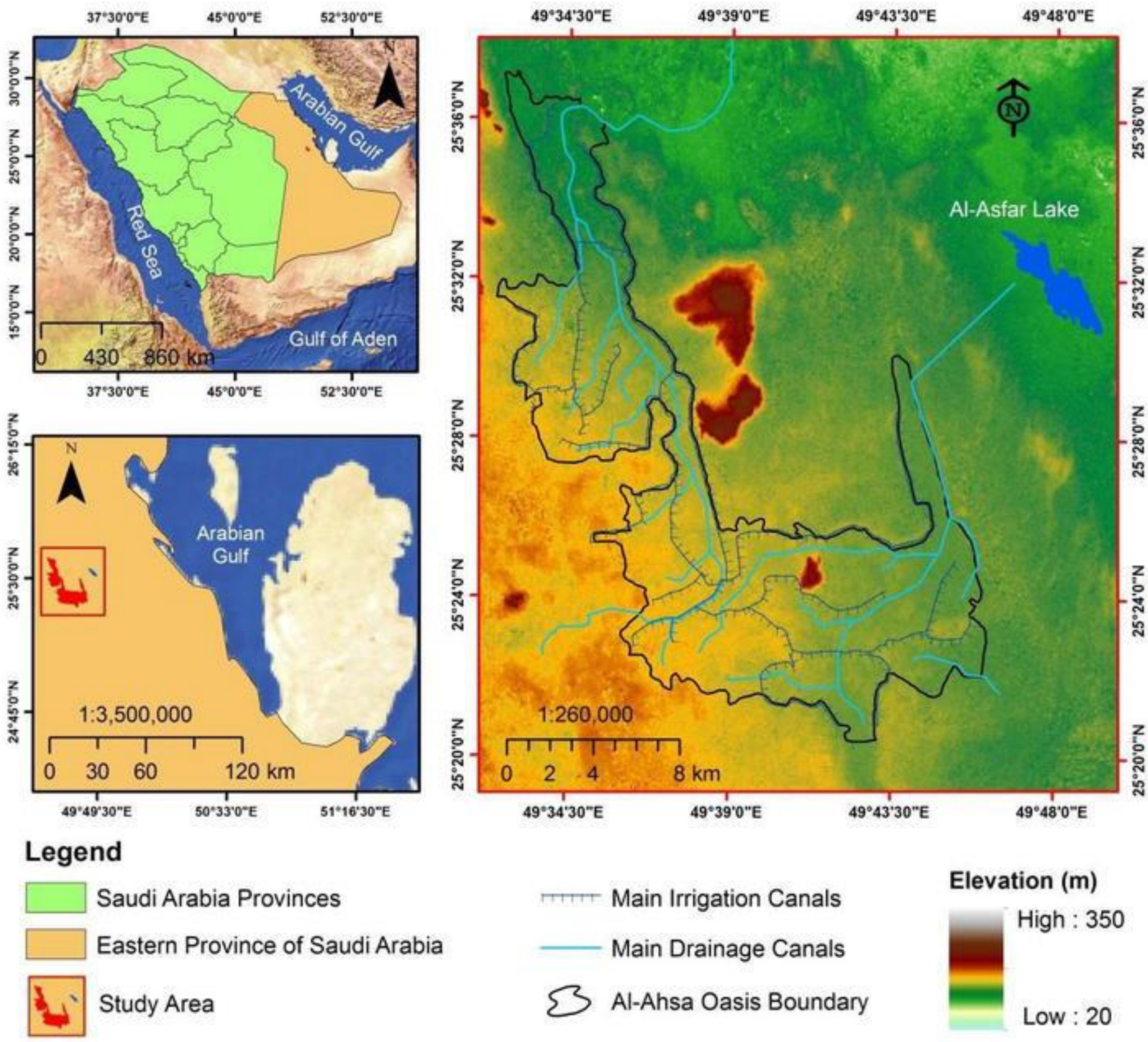

Figure 2: Satellite-based ET of the Al-Ahsa oasis used to grow dates, rice and vegetables [Turk *et al*, InTechOpen].

By combining hyperspectral and multispectral data, Saudi Arabia is creating maps to classify its soil to inform land use, ecological conservation and sustainability. Accurate categorisation is essential for planning and implementing renewable energy projects, such as solar farms and wind turbines, which require stable and suitable land. Moreover, understanding soil types can aid in the development of carbon capture and storage technologies, which rely on geological formations to sequester carbon dioxide.

Soil classification has identified areas for afforestation incorporating soil fertility, moisture retention and vegetation indices. These insights guide reforestation efforts, enhancing biodiversity and mitigating the impacts of climate change.

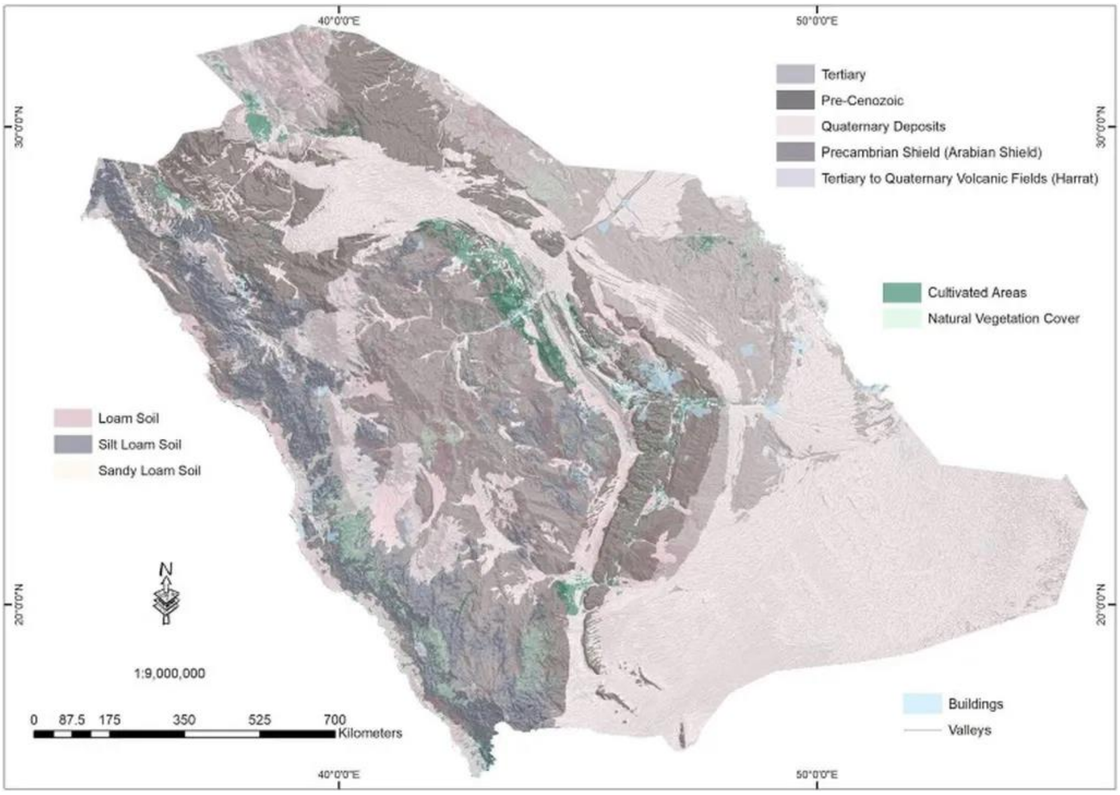

Figure 3 : Soil Classification Map of Saudi Arabia [John Hutton, AgriTech Insights].

Oil production accounts for approximately 40% of Saudi Arabia's economy, of which 80% is exported, generating around 75% of government revenue. Satellite technology is used to identify potential oil and gas deposits, *e.g.* hyperspectral imaging can detect surface mineral changes and vegetation stress caused by hydrocarbon seepage. Similarly, thermal sensors can measure variations in ground temperature due to gas escapes. Optical imagers identify geological features such as anticlines, faults and sedimentary basins, often associated with oil and gas deposits. These insights allow companies to pin-point their exploration to the most promising locations, avoid ecologically sensitive areas and minimise environmental damage. Traditional searches often involved extensive ground surveys which could be disruptive.

Satellite technology is also used to detect oil spills, map their extent and movement, support clean-up operations and impact assessment. SAR measures changes in surface roughness as oil films reduce wave activity, resulting in a smoother surface that produces less backscatter which appear as dark patches in the SAR image. Spillages can be accidental or illegal discharges, and SAR operates day and night, in all weather conditions. The following image of the 1991 Al Khafji oil spill was taken by the Sentinel-1 satellite.

Optical and multispectral imaging captures sunlight reflected from the water surface and detects oil through colour and spectral differences. Infrared sensors on-board satellites detect temperature differences caused by oil layers and are often used to verify and assess the thickness of spills.

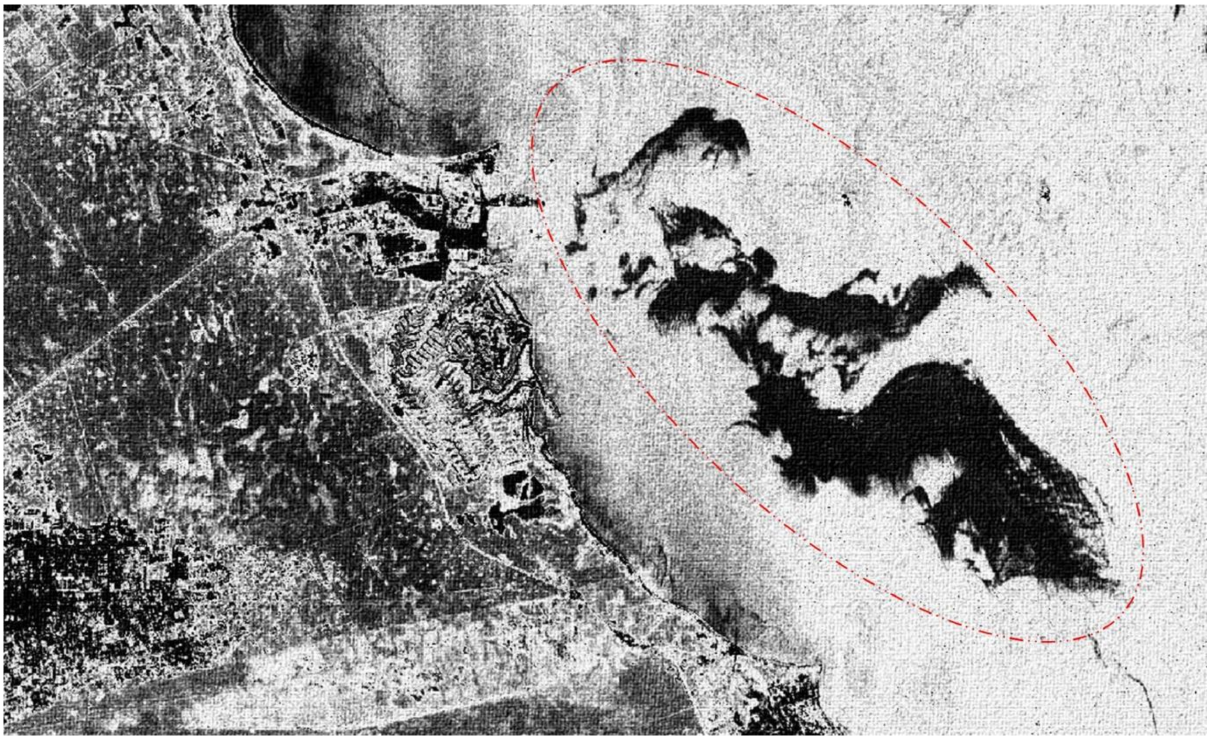

Figure 4 : Sentinel-1 SAR-C image of Al Khafji oil spill [Copernicus Open Access Hub].

SaudiSat 5A and 5B are high-resolution imaging satellites used for disaster management and their sun-synchronous orbits provide consistent lighting conditions and predictable revisit times to monitor and track oil spills, floods and wildfires.

To support a growing population and to deliver Vision 2030, Saudi Arabia's satellite communications market is expanding, driven by the need for reliable connectivity in remote areas and critical sectors like defence and maritime operations. The market is projected to grow from approximately $3 billion in 2024 to over $5.1 billion by 2030, with a CAGR of 9.4%.

Direct-to-device (D2D) satellite messaging using commercial smartphones has demonstrated seamless satellite-terrestrial integration to revolutionize connectivity across underserved regions. The Kingdom also recently approved the use of SpaceX's Starlink satellite internet service for aviation and maritime shipping as part of its efforts to enhance digital infrastructure and expand internet connectivity in remote areas.

To support the aspirations of Vision 2030, Saudi Arabia is developing indigenous capability and KACST is playing a key role in advancing the Kingdom's space technology, including STEM education, building satellites and participation in international collaborations to establish strategic autonomy.

Satellite technology is playing a pivotal role in advancing Saudi Arabia's infrastructure, economy and key initiatives. In addition to traditional applications such as telecommunications and defence, space-based solutions are being used to inform urban planning, manage water scarcity to ensure food security and sustainable agriculture, explore for oil and gas, disaster management and classify soil types to support reforestation.

Saudi Arabia has made major progress since the establishment of Arabsat in Riyadh in 1985 and the formation of the Saudi Space Commission in 2018. The Kingdom’s adoption of space technology offers an exciting, sustainable and prosperous future!

Figure 5 : Saudi space workers [SpaceTech in Gulf].

Spacechips is a multi-award-winning UK SME offering advanced, AI-enabled on-board processing products enabling customers to exploit the benefits of machine learning in-orbit in real-time.

Spacechips advises customers how to use and exploit satellite technology to solve local challenges, and teaches non-technical and technical courses on the New Space Economy, Earth Observation, Satellite-Systems Engineering, In-Orbit AI and Space Electronics. Spacechips will be teaching in Saudi Arabia towards the end of 2025!

Spacechips' Design-Consultancy Services develops bespoke hardware and software space-electronics' solutions for manufacturers of satellites and spacecraft, as well as providing advice on parts selection, how to design, test, assemble and manufacture space electronics.

Spacechips' Business-Intelligence Services help clients understand future technical and commercial trends for the space industry to define go-to-market strategies, identify target customers, market size and establish product roadmaps to guarantee ROI. Spacechips is advising the boardrooms of many diverse organisations around the world.

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