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Estimation of small reservoir storage capacities in the São Francisco, Limpopo, Bandama and Volta river basins using remotely sensed surface areas

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People living in areas with highly variable rainfall, experience droughts and floods and often have insecure livelihoods. Small multi-purpose reservoirs (SR) are a widely used form of infrastructures to provide people in such areas with water during the dry season, e.g. in the basins of São Francisco, Brazil, Limpopo, Zimbabwe, Bandama, Ivory Coast and Volta, Ghana. In these areas, the available natural flow in the streams is sometimes less than the flow required for water supply or irrigation, however water can be stored in times of surplus, for example, from a wet season to a dry season. Efficient water management and sound reservoir planning are hindered by the lack of information about the functioning of these reservoirs. Reservoirs in these regions were constructed in a series of projects funded by different agencies, at different times, with little or no coordination among the implementing partners. Poor record keeping and the lack of appropriate institutional support result in deficiencies of information on the capacity, operation, and maintenance of these structures. Estimating the storage capacity of dams is essential to the responsible management of water diversion. Most of SR in these basins have never been evaluated, possibly because the tools currently used for such measurement are labor-intensive, costly and time-consuming. The objective of this research was to develop methodology to estimate small reservoir capacities as a function of their remotely sensed surface areas in the São Francisco, Limpopo, Bandama and Volta basins, as a way to contribute to improve the water resource management in those catchments. Remote sensing was used to identify, localize and characterize small reservoirs. The surface area of each was calculated from satellite images. A sub-set of reservoirs was selected. For each reservoir in the sub-set, the surface area was estimated from field surveys, and storage capacity was estimated using information on reservoir surface area, depth and shape. Depth was measured using a stadia rod or a manual echosounder. For reservoirs in the sub-set, estimated surface area was used as an input into the triangulated irregular network model. With the surface area and depth, measured volume was calculated. Comparisons were made between estimates of surface area from field surveys and estimates of surface area from remote sensing. A linear regression analysis was carried out to establish the relationship between surface area and storage capacities. Within geomorphologically homogenous regions, one may expect a good correlation between the surface area, which may be determined through satellite observations, and the stored volume. Such a relation depends on the general shape of the slopes (convex, through straight, to concave). The power relationships between remotely sensed surface areas (m^2) and storage capacities of reservoirs (m^3) obtained were – Limpopo basin (Lower Mzingwane sub-catchment): Volume = 0.023083 x Area^1.3272 (R^2 = 95%); Bandama basin (North of the basin in Ivory Coast): Volume = 0.00405 x Area^1.4953 (R^2 = 88.9%); Volta basin (Upper East region of the Volta Basin in Ghana): Volume = 0.00857 × Area^1.43 (R^2 = 97.5%); São Francisco basin (Preto river sub-catchment): Volume = 0.2643 x Area^1.1632 (R^2 = 92.1%). Remote sensing was found to be a suitable means to detect small reservoirs and accurately measure their surface areas. The general relationship between measured reservoir volumes and their remotely sensed surface areas showed good accuracy for all four basins. Combining such relationships with periodical satellite-based reservoir area measurements may allow hydrologists and planners to have clear picture of water resource system in the Basins, especially in ungauged sub-basins.