WATER RESEARCH COMMISSION

April 2008

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

BIOFUEL PRODUCTION

The potential of the impact of large-scale planting of the biofuel crop *Jatropha curcas* was investigated.

Jatropha Curcas: Measuring the Impact of Large-scale Planting on Water Resources

Jatropha curcas production – A threat to South Africa's water resources?

New crop species introduced on a large scale have the potential of impacting on South Africa's water resources. International interest in ***Jatropha curcas*** as a drought tolerant, fast-growing crop, suitable for bio-energy production, has grown significantly in recent years. The crop has also been seen as a possible contributor to poverty alleviation and job creation. For these reasons, large-scale schemes for planting ***J. curcas*** have been proposed in South Africa.

The effective management of commercially planted species in terms of possible water resource impacts requires accurate information on generalised water use and bio-physical production characteristics relevant to areas having planting potential. With such information largely lacking in the case of ***J. curcas***, the Department of Water Affairs and Forestry (DWAF) has been forced to adopt a cautious approach and to propose that, until necessary information becomes available, the large-scale cultivation of ***J. curcas***, as with other new species having similarly uncertain water requirements, be declared a Stream Flow Reduction Activity (SFRA).

Uncertainty surrounding the effective use of water by ***J. curcas*** dictated that research be undertaken to develop a capability for predicting impacts of large-scale planting of ***J. curcas*** on water resources in South Africa. This research has entailed the acquisition of available information on the bio-physical requirements of ***J. curcas*** to enable mapping of areas suitable for planting, the provision of crop yield information for gauging production potential and the provision of water-use data as a basis for SFRA recommendations relating to large-scale cultivation of ***J. curcas***.

Review of world knowledge

The first step in the research process was to conduct an international review of available knowledge on the cultivation, hydrology and production of ***J. curcas***, a crop having many potential uses. This review provided some useful biophysical data, but also confirmed that relatively little is known about the ecological and hydrological impacts of *J. curcas*.

In addition, remarkably little information could be found anywhere in world literature on crop yields of ***J. curcas*** in relation to biophysical and prevailing climatic conditions, thus presenting an obstacle to reliable crop-yield prediction for potential production areas in South Africa.

Estimating yield of *J. curcas*

A crop modelling approach in three phases was consequently employed to obtain productivity estimates of ***J. curcas*** for different areas in South Africa, with modelling complexity increasing with each successive phase.

The first phase of modelling used biophysical cut-off limits, derived from the knowledge review, to eliminate all areas where ***J. curcas*** will not grow due to climatic and physical constraints.

The second phase sought to produce weighted estimates of potential crop yield by considering the relative importance of each of a number of index values related to overall crop yield. This assessment yielded similar results to those of the next (third) phase, in which crop-yield equations provided the means of estimating crop yield.

With crop-yield equations for ***J. curcas*** being absent from the international literature, the third phase required that crop-yield equations be derived. This was accomplished by manipulating existing equations for banana plantations, eucalyptus plantations and sunflower crops, taking into consideration the known tolerance limits of ***J. curcas*** itself.

The crops to which the existing equations apply have properties that encompass the oil-producing and tree-like growth properties of ***J. curcas***. Whilst the derived equations do not pretend to give precise yield estimates for ***J. curcas***, they are able to provide good indications of expected yield for a range of potential production areas.

Application of the crop-yield equations showed that the highest potential yields of ***J. curcas*** in South Africa are likely to be obtained in the coastal areas of KwaZulu-Natal and the Eastern Cape, as well as inland, along the eastern slopes of the Drakensberg mountains in Mpumalanga, where yields of over 8 t of seed/ha may be achieved. At the other extreme, low yields of less than 2 t of seed/ha can be expected in the northern parts of the country and along the south-eastern seaboard. The central interior is not at all suitable for ***J. curcas*** due to low rainfall and frost.

Water-use assessment

In order to establish the hydrological (water-use) characteristics of ***J. curcas***, it was necessary to make field measurements of crop transpiration. To this end, ***J. curcas*** plantings of two different ages were selected at appropriate test sites in two different areas (Empangeni and Makhathini Flats) representing optimal growing conditions. Over a period of almost two years, transpiration of ***J. curcas*** plants was continuously monitored through the measurement of sap flow using the Heat Pulse Velocity (HPV) technique. In addition, selected weather variables and, and, where possible, soil-water dynamics were monitored to provide the basis for the subsequent application of modelling as a means of simulating water use of ***J. curcas*** throughout potential production areas.

The measurement of transpiration rates revealed some interesting trends. Owing to the deciduous nature of ***J. curcas***, maximum transpiration rates in summer are followed by the cessation of transpiration in the cooler and drier winter months. Transpiration rates proved to be especially sensitive to rainfall events on soils with rapid drainage and low retention capacity for water in the root zone.

By scaling up from transpiration measurements made on individual trees, to transpiration estimates at plantation level, the total annual transpiration obtained for the four-year-old ***J. curcas*** plantation at Empangeni was about 144 mm. This compares with an approximate average value of 330 mm for a 12-year-old Makhathini stand, reflecting the greater age, size and greater overall leaf area of the Makhathini trees.

Water-use modelling and mapping

Out of three water-use models that were initially in contention, the FAO 56 model was considered to be the most appropriate and easily parameterised for the simulation of transpiration of ***J. curcas***. The subsequent simulation exercise thus followed the FAO 56 approach of employing calculated reference evapotranspiration, together with empirically determined crop coefficients.

For this purpose, a unique set of monthly basal crop-coefficient values for 4 and 12-year-old ***J. curcas*** trees were derived through back-calculation from the transpiration estimates obtained at Empangeni and Makhathini.

By using the modelling approach in a GIS environment, transpiration estimates for ***J. curcas*** could be mapped on a national scale. These estimates could then be compared with corresponding transpiration estimates for natural veld to determine whether ***J. curcas*** would transpire more or less water than indigenous vegetation types. The comparison (omitting the winter rainfall region) showed that water use by ***J. curcas*** is considerably lower than that of the original, natural vegetation.

It was immediately recognised that the apparently low transpiration estimates for ***J. curcas*** might be partly attributable to under-estimation of basal crop coefficients, with water-use experimentation having taken place during a low-rainfall period when there would have been a tendency for ***J. curcas*** to drop leaves.

By using an alternative approach to estimating transpiration, based on an empirical relationship between observed transpiration and leaf area index (LAI) measurements at both the Empangeni and Makhathini sites, it was confirmed that actual transpiration could have been about 50% greater than that estimated using the basal crop coefficients derived for dry conditions. **However, even with the LAI approach, *J. curcas* was still found to use less water than natural vegetation.**

Conclusion

Jatropha curcas can be most successfully grown in South Africa along the Eastern Escarpment and most areas along the coast. Places where highest yields would be obtained are in KwaZulu-Natal, the Eastern Cape and certain areas of Mpumalanga. Areas of low and variable rainfall, and areas susceptible to frost, **should be avoided**.

> It appears unlikely that cultivation of ***J. curcas*** would have a negative effect on annual streamflow in South Africa and should therefore not be considered a SFRA.

In reality very little is still known about the production potential of ***J. curcas*** in South Africa; further research, related both to water use and other aspects such as economics and invasiveness, is recommended.

Further reading:
Jatropha curcas in South Africa: An Assessment of Its Water Use and Bio-physical Potential (**Report No 1497/1/07**).
To order this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565 or E-mail: orders@wrc.org.za; Web: www.wrg.org.za