Land Use and Water Resources Research

Food security for sub-Saharan Africa: does water scarcity limit the options*?

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Abstract

Future food security can be achieved only by delivering substantial increases in agricultural production, but this has important implications for water availability. Water scarcity is not currently a major issue in sub-Saharan Africa, but it would be a mistake to neglect this issue. It would be a mistake also to assume that only plans for irrigated agriculture are affected. It should be recognised that a land-use decision is also a water-use decision. A plan based on improving rain-fed agriculture through adoption of measures to make better use of rainfall brings trade-offs in that there may be less runoff to satisfy the water needs of downstream users and environmental functions. Planning for future food security requires integrated analysis of land-use and water resources issues.

Keywords: food security, water scarcity, irrigation, agriculture, Africa

Introduction

It is not difficult to make a case for consideration of land resources in any discussion of food security. The case for consideration of water resources may be less immediately obvious and institutional barriers mitigate against their joint consideration. As long as water demands are low relative to water availability, there is little competition for resources and little recognition of the connection between decisions about land and water. However, growing awareness of the “world water crisis” is leading to increased recognition that water scarcity and food security are interrelated problems.

Management of water resources is closely related to the development goals of poverty eradication, socio-economic progress and environmental protection. Lack of access to water is now seen as a key constraint to development. Several major international consultation exercises have attempted to explore visions for the future and identify routes to achieving development targets, such as:

- Halve the proportion of people without access to safe drinking water by 2015;
- Halve the proportion of people without access to sanitation by 2015.

At the same time, another international development initiative has been focused on prospects for future food security with a view to achieving the target to:

- Halve the number of undernourished people by 2015.

These are formidable challenges and if they are to be tackled successfully then it is important to identify any conflict between them at the outset. On one hand it is desired to increase water allocations to domestic users and

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industries, but also it is necessary to make more water available for crop production, and at the same time we must secure ecosystem health on which human life ultimately depends. It is therefore necessary to ask:

- To what extent does future food security depend on expansion of irrigated agriculture?
- Is it feasible to ease the water crisis by increasing water productivity in agriculture?
- Can increased water productivity in agriculture (rain-fed and irrigated) enable food security to be assured without increasing water diverted to irrigation?
- Is development of more productive rain-fed agriculture hydrologically neutral?

Food security issues

Globally, we are making progress towards food security. This is clear from the substantial increases in *per capita* food supply; the proportion of people living in developing countries with an average food intake below 2200 kcal per day fell from 57% in 1964–66 to 10% in 1997–99. Nevertheless, we still face the stark reality that 800 million people suffer chronic under-nourishment of whom 25% live in sub-Saharan Africa (SSA). Because of population growth, projections show little chance of achieving the target of the 1996 World Food Summit (WFS) to halve the number of hungry people. While population growth in the region is about 3% per year, the growth in food production lags behind at about 2.5%. Projections (Table 1) show a continuing deterioration in food security for Africa while the rest of the world shows progress, albeit rather slowly, towards achieving the target (IFPRI, 2001).

Exceptionally high rates of agricultural growth will be required to come close to the WFS target and this has important implications for achieving poverty targets. About 70% of people in Africa (80% of poor people) live in rural areas and depend on agriculture for their livelihoods. Where will this growth come from? It is clear that management of land and water resources will play a critical role, as growth in food production will depend upon a combination of:

- Expanding cropped area;
- Increasing cropping intensity;
- Boosting yields.

The first option still exists for much of SSA. Analysis by FAO shows that soil/terrain/climate suitability would permit expansion, but realistically only a fraction of the ‘available’ land could be used if we wish to preserve forest cover and protect other interests. Constraints also exist in that new areas are likely to suffer poor access to markets and poor infrastructure (schools, health care, etc.). Previous experiences with comprehensive settlement schemes have shown that they are complex and problematic. However, the alternative is unplanned population shifts into marginal areas where land degradation is likely to occur without concerted action to avoid it. IFPRI (2001) predicts an increase of 20 million hectares under cereal production in SSA by 2020.

FAO projects that 25% of the increase in SSA food production to 2030 will come from expansion, leaving 75% dependent on boosting production from existing crop land through intensification. This requires action to boost yields through technological improvements: a second green revolution is called for and biotechnology is often hailed as

Table 1 Projected trends in under-nourishment

	1990-92	*1997-99*	*2015*	*2030*	*1990-92*	*1997-99*	*2015*	*2030*
		PERCENT OF POPULATION				MILLIONS OF PEOPLE		
Sub-Saharan Africa	35	34	22	15	168	194	184	165
North Africa	8	9	8	6	25	33	38	35

Source: FAO, 2003; FAO, 2001

Table 2 Land use and irrigation

	Arable area (million ha)			Harvested area (million ha)*		
	total	*rainfed*	*irrigated*	*total*	*rainfed*	*Irrigated*
DEVELOPING COUNTRIES						
2000	956	754	202	885	628	257
2015	1017	796	221	977	671	306
2030	1076	834	242	1063	722	341
SUB-SAHARAN AFRICA						
2000	228	223	5.3	154	150	4.5
2015	262	256	6.0	185	179	5.7
2030	288	281	6.8	217	210	7.0

Source: World Agriculture: towards 2015/2030 (FAO, 2003).

* note that under irrigation, ‘harvested area’ may include multiple cropping and therefore exceed ‘arable area’

the solution. This leads into the complex debate about reasons for historically low growth of agricultural production in SSA and low rate of adoption in agricultural technology. Previous experience shows that science-based improvements are difficult to achieve for the complex, diverse, risk-prone farming systems which dominate in SSA. An alternative paradigm (Pretty, 1999) calls for 'sustainable agriculture', which aims to reduce dependence on external inputs (fertilisers and pesticides) by making better use of nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests. In this case the required improvements are particularly knowledge-intensive and lead to very heavy demands on agricultural support services.

It is sometimes argued that "irrigation is fundamental to agricultural intensification". In 1997–99 irrigated land made up about 21% of total crop area in developing countries, but produced 40% of total production and as much as 59% of production of staple cereals (FAO, 2003). The distribution of irrigated land is strongly skewed towards a few countries and shows wide regional variations. Only 3% of irrigated land is in SSA and this represents less than 5% of arable land in the region (Table 2), which suggests that expansion may be a realistic option. However, the history of irrigation in most countries within SSA in the last 30 years has not been good and most existing schemes have considerable under-utilised potential. Nevertheless, the baseline scenario adopted by IFPRI (2001) projects that 25% of investment expenditure on food security in SSA will go to irrigation and in their 'optimistic scenario' this increases steeply. We will see that development of irrigation has serious implications for water resources and may be constrained by water scarcity.

Water scarcity issues

Water scarcity has not been a prominent issue on the development agenda for as long as food security, but it has gained increasing attention in recent years. As the world population tripled in the twentieth century, the use of water resources grew six-fold and one-third of the world's population now live in countries currently facing a water shortage. Forecasts by World Water Council (2000) indicate that 3 or 4 billion people will face water scarcity by 2025. Considerable regional variations are evident and SSA will not be affected as badly as some other regions, but avoidance of water scarcity cannot be at the cost of food security (or vice versa). The most immediately obvious uses of water are drinking, cooking, bathing and cleaning, but this domestic consumption is actually only a small part of the total demand. Global estimates show that twice as much water is withdrawn from the resource to meet industrial demand as for municipalities and eight times as much for agriculture (Table 3) This table shows that consumption is less than withdrawals because of return flows, but agriculture generally has a higher consumption/withdrawal ratio and the relative impact of this demand is therefore greater than for other users

There is no universally adopted measure of water scarcity but perhaps the one most widely used is the Falkenmark indicator based on *per capita* available water resources (Falkenmark *et al.*, 1989). Severe water stress is generally taken to correspond to less than 1000 m^3 per person per year. However this measure of 'demographic water scarcity' does not account for differences in seasonality/reliability of resources nor ability to manage them. A second indicator, therefore, is the ratio of water-use to resource availability. A threshold value of 40% is often taken to indicate high water stress (Raskin *et al.*, 1997).

Data presented in Table 4 indicate the situation across four regions of Africa for 1995 and also a projection for

Table 3 Global water use in the 20th century (in cubic kilometres)

*Use**	*1900*	*1950*	*1995*
AGRICULTURE			
Withdrawal	500	1100	2500
Consumption	300	700	1750
INDUSTRY			
Withdrawal	40	200	750
Consumption	5	20	80
MUNICIPALITIES			
Withdrawal	20	90	350
Consumption	5	15	50
RESERVOIR EVAPORATION	0	10	200
TOTALS			
Withdrawal	600	1400	3800
Consumption	300	750	2100

Source: World Water Council, 2000

* Note that data here refer to use of 'blue water' (see Box 1).

Table 4 An optimistic forecast of future water scarcity* in Africa

	Water available (km^3 per year)*	*Withdrawal ratio 1995* (%)	*Demographic pressure* (m^3 / c / yr) 1995	2025
North Africa	111	94.6	795	405
Southern Africa	442	5.5	5780	2710
East Africa	762	5.9	4525	1580
West Africa	1103	2.1	5525	2115

Source: Falkenmark, 1997

* Note that data here refer to 'blue water' (see Box 1)

2025. This projection allows for population growth but assumes no change in *per capita* water use. It is apparent that North Africa faces water scarcity but other regions do not. However, this apparently rosy picture changes if we consider future scenarios in which *per capita* water use increases. The 'business as usual' scenario analysed by World Water Council (2000) projects large increases in water withdrawals in the industrial and domestic sectors for developing countries. This leads to projections of significantly increased water stress in 60% of the world, including large parts of Africa.

An alternative future scenario represents the conventional wisdom in agriculture, which holds that future increases in food production will require an expansion of 20% to 30% in irrigated area. This leads to greatly increased problems of water stress as the agricultural allocation grows to satisfy this increased demand. Falkenmark (1997) considers a similar future scenario to be 900 m^3 per person per year, assuming a reasonable level of future demand which aims to permit food self-sufficiency under semi-arid conditions. To achieve this target at the projected 2025 population for West Africa would require a mobilisation level of more than 40%.

Neither alternative represents an attractive future scenario. One is likely to create serious problems of food security, while the other will create severe water scarcity. Bringing together considerations of food and water leads us to the unavoidable conclusion that we need to make water more productive. The slogan is "more crop per drop". The more food we produce with the same amount of water, the less competition for water, the greater the local food security and the more water will remain for other uses (including the environment). Critical questions are:

- Will future food security depend upon increased production from irrigated land or will it be achieved by a focus on improved rain-fed production?
- Is the WFS target achievable without increasing the water allocation to irrigation?

To answer these questions properly, it is necessary to adopt a more holistic approach. There is a strong tendency for discussion to focus only on the issue of 'blue water' and its allocation to irrigated agriculture (see Box 1). This neglects the large amount of 'green water', which supports rain-fed agriculture. For any catchment, all inputs originating as precipitation flow into one of these stocks and partitioning between them is heavily dependent on land use. Actions that affect land cover and 'green water' therefore have implications for 'blue water' and both contribute to food production.

Box 1: Water comes in several colours

Blue water = the portion of rainfall that enters into streams and recharges groundwater
· traditional focus of water resources management
· supports aquatic ecosystems

Green water = the portion of rainfall that is stored in the soil and returns as vapour flow (including both productive and non-productive evapotranspiration)
· basis for rain-fed agriculture
· supports terrestrial ecosystems

More crop per drop in rain-fed agriculture

In SSA the current level of dependency on irrigated land is very low (see Table 2) and rain-fed agriculture (using 'green' water) plays the central role in sustaining rural livelihoods and meeting food requirements. The challenge in this case is to improve crop production *per drop of rain*. Rainfall is generally erratic, with intensive storms and intermittent dry spells which together limit production, even where the seasonal total is reasonable. Improving crop production therefore depends in part upon overcoming soil-moisture problems, which can be categorised as those related to water-entry and retention, and those related to subsequent use by plants (see Box 2). On the other hand, inadequate rainfall or its inappropriate distribution may require measures to import additional water.

A significant knowledge gap exists between two areas that have previously received far greater attention in response to these problems. On one hand, widespread concern about land degradation has led to a focus on soil erosion control (domain of soil scientists). On the other hand, efforts to exploit water resources have led to a focus on irrigation (domain of water engineers). Between these two extremes, the middle-ground of rainwater harvesting (RWH) has, until recently, been largely neglected (Gowing *et al.*,1999; Rockstrom, 2000). Rainwater harvesting should be seen as a continuum of techniques that links *in-situ* soil-water conservation at one extreme to conventional irrigation at the other. It is a broad umbrella term, which includes all methods of collecting runoff for productive use. Key

Box 2: Soil moisture problems limiting rain-fed production

Problem type 1: Overall inadequacy of rainfall or inappropriate distribution

· Cropping of whole field not feasible due to insufficient rainfall (relative to evaporative demand) for all or part of the crop growing period;
· Cropping of whole field normally feasible, but yields diminished by unpredictable dry spells which occur during the crop growing period.

Problem type 2: Slow acceptance of rainwater by soil

· Water acceptance hindered by low rate of infiltration due to soil surface condition (surface sealing) leading to high runoff loss;
· Water acceptance hindered by low percolation rate caused by compacted or impermeable sub-surface layers.

Problem type 3: Insufficient storage of plant-available water in the soil profile

· Limited soil moisture retention capacity with the root-zone due to soil texture leading to rapid drainage of infiltrated water;
· Soil depth available for storage of infiltrated water is less than potential rooting depth of crop due to shallow profile or compacted layer.

differences are (i) source of water, (ii) scale or transfer distance and (iii) method of managing the water.

In-field RWH techniques aim to collect rain falling onto the farmer's field and detain water within the field to ensure that it infiltrates and is stored in the crop root-zone. Conservation tillage aims to achieve this by increasing surface storage, by overcoming surface sealing, or by sub-soiling to break up restrictive layers deeper within the profile. Many authors (e.g. Wallace, 2000) discuss evidence for the improvements that have been achieved with these methods, but they do not overcome problem type 1 (Rwehumbiza *et al*., 1999). Some techniques deliver additional water to the crop by allowing within-field runoff over short distances so that it concentrates in part of the field. Such techniques are often called micro-catchment RWH and include contour bunds, contour strips, trash lines, terraces etc. (Gowing *et al*., 1999). This involves sacrificing part of the field so that it functions as a runoff-producing area and does not produce a crop. Where land is scarce the increased yield from the cropped area may not be sufficient to compensate for lost yield from this uncropped area (Hatibu *et al*., 1999). All in-field techniques suffer the same limitation in that they offer little protection from poor rainfall distribution and the risk of crop failure is still high.

The use of external catchments for runoff collection brings additional water to the field water balance and this may occur at times when there is no direct rainfall. These techniques are known as macro-catchment RWH (Gowing *et al*., 1999) or spate irrigation. They depend on ephemeral flows in small streams and gullies, which are often diverted into cropped field at the footslopes of steep hilly areas but may also be possible where flow concentration occurs due to road and railway culverts. Substantial channels and runoff control structures may be required and this usually involves collective effort amongst a group of farmers.

Macro-catchment RWH systems involve greater modification of natural water flows and have been shown to be very effective in drylands where absolute water scarcity is common. Nevertheless, the degree of control over amount and timing of water supply to the root zone is very limited and the farmer is still at the mercy of dry spells. Storage systems offer the farmer greater control, but the investment cost and need for know-how are increased. Such systems allow the farmer to practise supplementary irrigation during stress periods. Where the water has to be lifted from the storage structure to the cropped field, the energy requirement becomes a problem, but if topography is favourable then this can be avoided. Such systems are not common in SSA although they exist widely in parts of South Asia. If provision of increased water storage is seen to be critical to future water management and food security (World Water Council, 2000) then perhaps this may be the most appropriate scale for developing additional storage in SSA. Certainly there is scope for greater attention to RWH generally.

More crop per drop in irrigated production

Irrigation depends upon 'blue' water and in this case the challenge is to improve crop production *per drop of water diverted from rivers or pumped from groundwater*. It is often argued that irrigation systems operate at low levels of efficiency and improvements are easily achievable, thus allowing water savings which can be reallocated to other uses. However, such conclusions are based on incomplete analysis and erroneous extrapolations. Recent comparisons of field-scale and catchment-scale measurements show that real savings are often difficult to make (Seckler, 1996).

Efficiency is a tricky concept in that it considers all non-productive uses of water at the field scale to be 'losses', but if we redraw the systems boundary to include a larger area, then some of the drainage water becomes available for re-use. Real gains in water productivity depend upon the existing extent of reuse, whether for irrigation or some other purpose (possibly including environmental requirements). In some intensively irrigated basins (e.g. River Nile in Egypt) the overall water use efficiency is close to 80%, despite field-scale efficiency of around 40%. Wallace (2000) and Seckler *et al*. (1998) discuss this multiplier effect. It should also be noted that the process of recovery may occur by groundwater pumping as in the extensive irrigation systems of the Indus Basin.

Real improvements in water productivity may not be achieved so easily by tinkering with irrigation systems and practices, rather they depend upon targeting interventions on:

- increasing output *per drop of evaporated water;*
- reducing real losses to 'sinks' from which re-use is not feasible (possibly due to degraded quality).

Better water management can bring increased output by improved timing and/or reliability so that water supply is properly matched to crop demand. This requires making irrigation system operations more responsive to the needs of farmers. In canal systems this is difficult to achieve and attempts to improve efficiency in this way can lead to equity problems. It is a mistake to assume that the policy of 'management transfer' (Sam-Amoah and Gowing, 2001) will help in this respect. Game theory (prisoner's dilemma) tells us that when faced with water scarcity, top-end farmers are more likely to 'steal' water than to restrict their use. Similarly, it is a mistake to rely on another much-advocated policy of charging for irrigation water in order to limit excess use. This requires pricing water on the basis of the actual volume used by an individual farmer, which is possible only if the supply is measured volumetrically and is not a realistic possibility in most irrigation systems.

There are severe challenges that must be tackled to realise the water savings anticipated by advocates of options such as 'supplementary' irrigation, 'deficit' irrigation or 'precision' irrigation. The first of these involves making limited amounts of water available at critical times to crops which are otherwise rain-fed. It is a strategy which has been shown to work well where farmers control their own supply, but is difficult and expensive to implement in multi-user systems. The second option also does not attempt to meet full crop demand and assumes that farmers will optimise their use of limited irrigation water. This can be achieved by careful timing of applications to avoid stress at critical growth stages. The third option can deliver similar benefits by reducing non-productive soil evaporation but may require costly and complex micro-irrigation technology (also known as drip and/or trickle), although Wallace (2000) and FAO (2001) suggest that simpler and more affordable variants of these technologies are being developed.

All of these strategies are aimed at delivering "more crop per drop" from the blue water resource, but it is not only agriculture that delivers significant 'waste-water' return flows. Global estimates (World Water Council, 2000) indicate 90% return flow from industry and 85% return from municipalities (i.e. domestic users). There is obvious potential for this so-called 'grey' water to be used for irrigation, particularly in the context of peri-urban agriculture. Development of this resource depends upon collection of waste-water in a sewerage system and would be linked to urban water supply and sanitation improvements.

It is imperative to recognise that productivity of water in irrigation systems is not a simple matter of 'crop per drop' in that the water may also be used for other purposes. These non-irrigation uses include livestock watering, bathing, laundry, fishing and micro-enterprises (e.g. brick-making). In general they are non-consumptive uses, which do not create additional demand, but they do generate additional production. In the past, they have been largely neglected in evaluating returns on investments in irrigation but they can have important implications for livelihoods of poor rural people (Meinzen-Dick and Van der Hoek, 2001).

Conclusion

Future food security can be achieved only by delivering substantial increases in agricultural production, but this has important implications for water availability. Crop efficiency in converting water into biomass is essentially the same whether the crop is rain-fed or irrigated. Some technical improvements may make it possible to increase this conversion rate, but it is inevitable that increased food production means increased water use by crop plants. Visions for the future developed by the World Water Council (2000) and FAO (2001) allocate part of the increase to irrigated production (blue water) and assume that the rest will come from rain-fed production (green water).

The WWC vision for 2025 assumes 40% more food will be produced and this will require a 9% increase in the consumption of blue water by irrigated agriculture. In this scenario the irrigated area expands by 5% to 10% . Significant improvements in water productivity are required to meet projected large increases in use of blue water by industry and municipalities in developing countries. The FAO vision for 2030 projects that future food security will be dependent on irrigated agriculture for 70 to 80%. An expansion of 23% in the irrigated area is projected, together with a 12% increase in blue water consumption by agriculture. In some countries (notably Nigeria) the projected increase in water withdrawal for agriculture actually exceeds 100%.

Both organisations make passing references to the importance of rain-fed production using green water but do not explore the implications. A proper analysis of food security for SSA requires a holistic consideration, embracing both blue and green water and a realistic assessment of what can be achieved by both irrigated and rain-fed agriculture. We have seen that in the context of the farming systems of SSA, there is in fact a fuzzy distinction between them. In both cases the difficulties of delivering required improvements should not be underestimated. It is likely that they will be knowledge-intensive and that they will depend upon better water productivity.

Water scarcity is not currently a major issue in SSA, but it would be a mistake to neglect this issue. Given projected population increases and reasonable demand assumptions Falkenmark (1997) showed that a balance of 50% blue water use and 50% green water use to support food production leads to water scarcity for many parts of SSA by 2025. It would be a mistake also to assume that only plans for irrigated agriculture are affected. It should be recognised that a land-use decision is also a water-use decision. A plan based on improved rain-fed agriculture and increased use of green water brings trade-offs in that there may be less blue water for downstream users and environmental functions. Planning for future food security requires integrated analysis of land-use and water resources issues.

References

Falkenmark, M., Lundqvist, J. and Widstrand, C., 1989. Macro-scale water scarcity requires micro-scale approaches: aspects of vulnerability in semi-arid development. *Natural Resources Forum* **13**: 258–267.

Falkenmark, M., 1997. Meeting water requirements of an expanding world population. *Phil Trans R. Soc. Lond.* **B 32**: 929–936.

FAO, 2001. *Crops and drops: making the best use of water for agriculture*. FAO, Rome.

FAO, 2003. *World Agriculture: towards 2015/2030*. FAO, Rome.

Gowing, J.W., Mahoo, H.F., Mzirai, O.B. and Hatibu, N. 1999. Review of rainwater harvesting techniques and evidence for their use in semi-arid Tanzania. Tanzania *J. Agric. Sci.* **2**: 171–180.

Hatibu, N., Gowing, J.W., Mzirai, O.B. and Mahoo, H.F., 1999. Performance of maize under micro-catchment rainwater harvesting in Western Pare Lowlands and Morogoro, Tanzania. *Tanzania J. Agric. Sci*. **2**: 193–204.

IFPRI, 2001). *2020 Global food Outlook: trends, alternatives and choices.* International Food Policy Research Institute, Washington DC, USA.

Meinzen-Dick, R. and Van der Hoek, W., 2001. Multiple uses of water in irrigated areas. *Irrig. & Drainage Syst.* **15**: 93-98.

Pretty, J., 1999. Can sustainable agriculture feed Africa? New evidence on progress, processes and impacts. *Environ., Develop. & Sustainability* **1**: 253–274.

Raskin, P., Gleick, P., Kirschen, P., Pontius, G. and Strzepek, K., 1997. *Water futures: assessment of long-range patterns and problems*. Stockholm Environment Institute, Stockholm, Sweden.

Rockstrom, J., 2000. Water resources management in smallholder farms in Eastern and Southern Africa. *Phys. Chem. Earth* (*B*) **25** : 275–283.

Rwehumbiza, F.B.R., Hatibu, N. and Kishebuka, S.R., 1999. Evaluation of ccntour barriers for soil & water conservation in Western Pare Lowlands, Tanzania. *Tanzania J.Agric. Sci.* **2**: 181–192.

Sam-Amoah, S. and Gowing, J., 2001. The experience of irrigation management transfer in Ghana: a case study of Dawhenya irrigation scheme. *Irrig. & Drainage Syst.* **15**: 21–38.

Seckler, D., 1996. The New Era of Water Resources Management: from "dry" to "wet" water savings. Research Report 1. International Irrigation Management Institute, Colombo, Sri Lanka.

Seckler, D., Amarasinghe, U., Molden, D. de Silva, R. and Barker, R., 1998. World Water demand and Supply, 1990 to 2025: scenarios and issues. *Research Report 19*. International Water Management Institute, Colombo, Sri Lanka.

Wallace, J.S., 2000. Increasing agricultural water use efficiency to meet future food production. *Agric., Ecosyst. & Environ*. **82**: 105–119.

World Water Council, 2000. *World Water Vision: making water everybody's business*. London, Earthscan Publications.