

4.2 Liming materials

Widespread soil acidity is a common soil-related constraint to crop production in many parts of the world including sub-Saharan Africa. High leaching rates, unfavourable parent materials and, in some rare cases, the continuous application of acidifying chemical fertilizers such as ammonium-sulphates are largely responsible for high soil acidity. However, the main constraint for crop production in highly acidic soils is not so much the high amount of H^+ but the increased concentration of highly toxic Al^{3+} at low pH, and low exchangeable Ca^{2+} levels (Sale and Mokwunye 1993).

Agricultural liming materials are those whose Ca and Mg compounds are capable of neutralizing soil acidity. Liming materials such as limestones, dolomites and calcined and slaked limestones (lime) are used to raise the pH of acid soils, provide Ca-ions, and decrease Al-toxicity. Finely ground limestone and dolomite resources have been applied to acid soils for centuries and are still being applied in many countries of the world. There are several types of limestones: sedimentary bedded or massive limestone, dolomitic limestone, calcitic dolomite and dolomite. Marble is the term used for metamorphosed limestone or dolomite. Calcretes are carbonates formed by in-situ cementation of pre-existing material, and by precipitated calcium carbonate in near-surface environments. When dolomite is dominant in the calcretes it is called dolocrete. Calcretes can be earthy and soft, or form highly indurated hard crusts. Travertine, another form of calcium carbonate, is formed by rapid chemical precipitation from surface or groundwater, or by evaporation around natural springs. Travertine can be hard and compact, layered and banded, or porous and spongy. 'Tufa' is the name for a soft, spongy and porous variety of travertine. Marl is soft $CaCO_3$ mixed with various amounts of clay and organic matter. It is found mainly in swampy areas and in reservoirs, and in certain sedimentary successions.

Traditionally, liming materials are evaluated according to their neutralizing value (measured by titration) and fineness (measured as particle size distribution), and in a combined form, the 'agricultural index.' Typical ground limestone has a neutralizing value of 100%, dolomite 106% and agricultural hydrated lime, after energy intensive calcination, 136%. Other ways of assessing the expected performance of liming materials is by surface area, chemical composition and solubility. While the fineness is expressed as particle size distribution of ground and sized material, the surface area is expressed as the total surface area of the liming material. The surface area does not necessarily correlate with the particle size analysis as internal pores, cracks and irregular surfaces largely increase the surface area. Only in very finely ground materials, surface area and particle size show strong correlation (Conyers *et al.* 1996). Liming materials from coral limestone and 'earthy limestones' often contain aragonite as form of $CaCO_3$, which is slightly more soluble than calcite. Dolomite is less soluble than calcite.

The application of limestone/dolomite as 'agricultural lime' is of benefit to the farmer where costs of production and transport are relatively low. Dolomite or limestone resources developed close to actively cultivated acid soils will be able to raise the pH of acid soils, creating favourable conditions for increased crop production. The mineralogical reactivity and chemical solubility and the kinetics of dissolution of liming materials play major roles in determining their agronomic effectiveness.

Some farmers utilize fast acting 'quicklime' as primary liming material for acid soil. Quicklime is a product of calcination ('lime burning') of limestone between 900 and 1200 °C. The calcination process requires considerable energy (often from fuel wood), thus increasing the energy costs for the production of liming material for agricultural purposes. When choosing to use agricultural limestone or dolomite instead of calcined lime, the rocks are mined, and crushed and finely ground only. Certainly these are energy intensive processes as well, but are often the only processes needed to get an effective agricultural limestone product.

The quality and processes for the production of agricultural 'liming materials' have to be assessed critically. Carbonate rocks are typically assessed by professionals who look for cement grade limestones,

by 'cement geologists.' More than 3-5% MgO is detrimental for the production of cement, but for agricultural application the Mg-component could be beneficial.

Farmers often prefer sedimentary limestones and coral limestones over more crystalline metamorphosed limestones and marbles. Unless the marbles are very finely ground the efficacy of the much finer and more porous sedimentary limestones is usually higher than the crystalline limestones. Reducing the grain size of limestones through fine grinding increases their agricultural efficacy.

The size of limestone and dolomite mining operations for agricultural lime production vary from country to country, but range from several thousand tonnes per month to small operations with only a few tonnes per cropping season. In cases of application to soils with low buffering capacities it is often not advisable to calcine the limestone/dolomite but to use them directly. While calcined and hydrated limes are more soluble, they are caustic and will 'burn' the roots of emerging plants if applied shortly before seeding or too close to the seeds. The application of uncalcined limestones also saves wood, the main energy source for such calcining operations.

The application rate of lime or limestone/dolomite depends largely on the pH, the Al^{3+} concentration and buffering capacities of soils, but is generally in the range of 2-4 tonnes per hectare. Since large quantities of liming materials are required per unit of land and since these materials are low-value high-bulk products, it is of utmost importance to find local sources to keep transportation costs reasonably low.

As the mineralogical and chemical parameters of liming materials vary strongly from place to place it is important to assess these parameters along with soil testing prior to application.

Alternative liming materials to be considered include wood ash, and several industrial byproducts such as slag and fly ash. Wood ash (Ohno and Erich 1990) and industrial byproducts (see chapter 4.10) have liming properties but can also provide other nutrients, for example, modest amounts of P and Ca.

Termite mounds, known for their naturally enhanced soil fertility, also have some liming properties. They are used in some parts of sub-Saharan Africa as soil amendments to increase the pH, provide additional soil organic matter and free $CaCO_3$ (Watson 1977; Moormann and Kang 1978; Nyamapfene 1986).

Like other industrial minerals, there are some important technical, economic and environmental considerations for mining of limestone/dolomite that have to be addressed. They include location, form of deposit (bedded/layered or massive, inclined or horizontal), nature and thickness of the interbedded rock materials, as well as chemical and physical characteristics. It is also important to determine the amount of overburden that has to be removed. It is critical to find energy resources for mining and calcination that are the least environmentally harmful and to determine low-cost, adapted beneficiation techniques (drying/crushing/grinding/physical concentration) suitable for the specific site. More energy efficient kilns can reduce wood consumption. Spiropoulos (1991) reported an example of the effectiveness of improved vertical-shaft kilns adapted to suit the specific conditions in Malawi. Lime is applied to the soils in different forms, but mostly it is broadcasted and later incorporated into the soil. Another method of making optimal use of agricultural lime is the application of lime in lime seed pellets (Pijnenborg and Lie 1990). Small amounts of lime are coated together with rhizobia species onto wet seeds to create evenly coated lime pellets. The pellets were field tested and showed early root development on legumes, as well as increased nodulation of various legume species (Pijnenborg and Lie 1990).

The case of liming materials illustrates the great advantage of the active cooperation between soil scientists, geologists and process engineers. Soil scientists outline the areas with high soil acidity which require liming materials and geologists search for agricultural limestone and dolomite resources close to the acid soils. Even if the carbonate resources are only of small extent and not of the quality required for cement manufacture, they may be suitable for improving the local acid soils.

The success stories of the use of liming materials in Rwanda (Yamoah *et al.* 1992) and Brazil (Sanchez and Salinas 1981; Goedert 1983) demonstrate that even small locally produced limestones and liming materials can be used to increase crop production on acid soils. Locally available carbonate resources such as calcitic and dolomitic marbles, carbonatites, sedimentary marine and lacustrine limestones, and secondary limestones (calkretes) are relatively common in many countries of sub-Saharan Africa and are well suited for small-scale mining and processing. Many more small limestone resources should be mined and, with some advice from agricultural extension personnel, applied on many more acid soils of the tropics.